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Technical Report: NAVTRADEVCEN 297-3

EFFECTS OF PROGRAMMED PERCEPTUAL TRAINING ON THE LEARNING OF CONTACT LANDING SKILLS

U.S. NAVAL TRAINING DEVICE CENTER

PORT WASHINGTON, L.I., NEW YORK

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Abstract

This project consisted of an experiment on the effect of one type of perceptual ("open-loop") training on the learning of contact landing. Thirty non-pilots, divided equally into two matched groups, participated. The experimental group received perceptual training with a programmed visual display; the control group did not receive this training. As criterion trials, both groups performed contact landings in an operational flight trainer equipped with a non-programmed visual attachment. The results indicated that the programmed presentation evaluated did not contribute to the learning of contact landings.

The implications of the findings, and research issues in the evaluation of visual attachments and of pilot performance are discussed.

FOREWORD

Introduction and Purpose

The great expense and complexity of non-programmed ("closed-loop") visual attachments to flight simulators coupled with the equally great need for contact landing training in simulators has provided a strong incentive for the analytic study of contact landing skills and their acquisition. The relative importance and the interaction of the perceptual-motor elements in landing tasks must be clearly known before visual attachments can be designed. One of the first questions to be decided is the degree to which the display must be sensitive to inputs from the trainee in the flight simulator, i.e., the degree to which the attachment must be non-programmed. Whereas there is much evidence to prefer the non-programmed presentations, we must not neglect any opportunity to exploit the potential value of the much cheaper programmed ("open-loop") visual displays even if we expect them to substitute only partially for non-programmed presentations or actual aircraft landings. The purpose of this research, therefore, was to evaluate the contribution of one type of programmed presentation--"perceptual-verbal pretraining"--to the learning of a contact landing task. Since the perceptual aspect can be regarded as a component of the whole landing task, this study also bears upon the part-task versus whole-task learning controversy.

Method

Subsequent to several hours of classroom and simulated instrument flight training, thirty naive subjects were divided into two equivalent groups. The experimental group obtained open-loop training which required them to judge a series of programmed correct and incorrect presentations of landing patterns and to identify the cause of errors. The other group served as control - i.e., it did not get open-loop practice. Then, each of the 30 subjects was required to perform a series of landing problems in the contact analogue landing research tool.

Several side issues concerning methodology for evaluating pilots as well as visual attachments were also raised and investigated.

Results and Implications

The programmed visual presentation did not aid in the learning of the contact landing task. This indicates the existence of a strong interaction factor between the perceptual and motor components which could not be learned with our programmed presentation. However, the failure of one type of programmed presentation--even though a promising one on a priori grounds--should not lead us to automatically rule out the possibility of success for a programmed presentation of greater length, different type, or different position in the learning cycle.

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BRIEF OF STUDY

Until quite recently all flight simulators were devices for training in instrument flying and procedures, with no means of training the numerous responses that a pilot must make to extra-cockpit contact cues. Flight training programs require that these responses be learned in the actual aircraft, and this can mean danger, expense, and a dependence on weather. Currently there is active research and development work on visual simulation equipment to be used in conjunction with flight simulators. In general, these new devices provide for closed-loop simulation where the pilot's inputs to the controls of the simulator change the position of the simulated aircraft with respect to the display, the display changes accordingly, the pilot responds again to the new display configuration, etc.

A persisting interest of training research personnel has been the development of part-task trainers that can accomplish the same training job with far less equipment involvement than a whole-task simulator that strives for realistic hardware simulation and the resources for practicing complete mission sequences. The cockpit procedures trainer is an example, where normal and emergency cockpit procedures are practiced independently of concurrent flight control of the system. A similar approach can be suggested for the simulation of visual cues, where a relatively simple training film might be devised to teach the perceptual cues and relationships in the visual scene, quite apart from the flight control and procedural responses that have to be made to them in the cockpit. The psychological rationale for this approach would be that an important part of complex perceptual-motor learning is resident in the acquisition of mediating responses that perform a selective, cueing function for the overt motor responses that position the aircraft. Whether such an approach would have a positive transfer effect to the complex whole task of flying the aircraft in reference to the visual cues, or whether it would have a zero or even a negative effect, is not known at this time. The efficacy of part-training methods and devices is an empirical matter that must be examined by experiment.

A laboratory experiment was performed with the Contact Analogue Landing Research Tool (Device 20-L-10a), which simulates an SNJ aircraft and the contact runway cues of a night landing pattern. Náive subjects were used. They were first administered a flight training program to teach them the basic principles of flight before they flew the experimental equipment on criterion runs. Fifteen subjects were in a group. An Experimental Group had prior exposures to the landing display in a series of open-loop programmed patterns where they were required to judge the presence or absence of errors in the landing pattern and, if an error was present, to judge its type and its initiating cause. This perceptual-verbal pretraining was followed by criterion flights in the Contact Analogue Landing Research Tool. A Control Group had only the criterion flights.

No differences were found between groups on measures of criterion performance, and it was concluded that the methods of perceptual-verbal pretraining that were used do not justify at this time the development of simplified part-task training devices for learning the relationships present in complex visual cues. However, other experiments were urged to extend the findings of this first experiment.

Supplementary data were collected from eight experienced professional pilots. These data had no bearing on the main experiment, but it was thought that they would elaborate our understanding of flying behavior in this new and complex piece of simulation equipment. The findings were considered provocative for the hypothesis of Phenomenological Equivalence and were given preliminary interpretation in terms of new approaches for the training validation of contact simulation devices.

DETAILS OF THE STUDY

INTRODUCTION

Until quite recently, all flight simulators (Operational Flight Trainers or OFTs in the standard Navy designation) were devices for training in instrument flying and aircraft procedures. The simulation of the aerodynamic characteristics of an aircraft gave realistic instrument indications for the flight control settings made by the pilot in the cockpit, with the result that he could practice a wide range of flight responses that must be made to the intra-cockpit cues. Similarly, OFTs could be used for training in the multitude of normal and emergency procedures that are required for proficient and safe flying. Without meaning to underplay the large training contribution that flight simulators have made in the learning of basic flight skills, the scope of their training capability has been limited to responses whose cues originated within the cockpit (Adams, 1957). Because pilots base a relatively large number of critical responses and decisions on extra-cockpit contact cues, the absence of these cues in OFTs has restricted their training capabilities and has necessitated that all responses to contact cues be learned in the aircraft itself. For the novice this can mean danger, particularly for practicing the critical contact maneuvers of takeoff and landing where a majority of all aircraft accidents occur. Too, use of the aircraft for these training routines means inability to practice dangerous emergency procedures, and a dependence on weather.

In recent years there has been an increased interest in the development of additional subsystems for flight simulators to simulate critical classes of visual cues, and to give simulators a capability for training beyond instrument flying and procedures. The absence of visual cues has been a shortcoming of unknown magnitude for flight simulators, but now the need for them has become greater than ever before because of the higher demands placed on a pilot's flying skill by high performance aircraft, and because the complexities of modern aircraft ordinarily function to reduce the amount of flying time and practice opportunities. While most developments in contact simulation are in research and testing stages, with little use of them as yet in operational flight training programs, the prospects of simulating an extensive range of critical visual cues are excellent for the future. Primary engineering attention has been given to the simulation of runway dynamics for the practice of takeoff and landing, but efforts also are being directed toward complex contact cues for helicopter hovering, air-to-air gunnery, visual reconnaissance, in-flight refueling, and other flight tasks. It is not unrealistic for the future to expect high fidelity simulation of many critical classes of visual cues for relatively long flying sequences. Contemporary American developments for visual simulation need not be reviewed here because they have been thoroughly summarized by Lybrand et al (1958a, 1958b) and Molnar and Lybrand (1959a, 1959b). The French also have been active in this area, and some of their equipment has been reviewed by Xhignesse (1958).

Historical Background of Simulating Contact Landing Cues

This report covers an experiment on an issue in the simulation of visual cues in contact landing, and this section is an historical account of research on the training value of simulating contact landing cues. One of the first studies to investigate the training value of simulated contact cues was by Brown, Matheny, & Flexman (1950). Contact maneuvers, primarily landing, were practiced by naive subjects in the School Link Trainer which has the approximate characteristics of a light plane, and the subjects were then transferred to the aircraft and scored in their performance in the actual flying of these maneuvers. Control subjects only flew the aircraft. The equipment for simulating visual cues was crude, but the study deserves discussion because of its historical role and the stimulus that it gave to the development of more sophisticated equipment. The basic device for contact simulation was a blackboard on which was drawn a runway outline. The blackboard could be moved by the instructor who would continuously orient the runway image in a semi-realistic fashion to illustrate how runway cues continually change during landing. This may be regarded as a quasi-closed-loop simulation because in a very approximate fashion the cues changed in accordance with the pilot's inputs to the system by way of the monitoring instructor who observed the pilot's instruments and then inserted his estimate of how the visual scene should appear. Another item of simulation was a cloth cyclorama with a horizon line painted on it. The number of subjects in this experiment was small, but the investigators found that the experimental group having prior practice in the Link trainer and its supporting devices for simulating contact cues was significantly superior in the landing of an aircraft to a control group that had no prior simulator experience.

A more systematic and comprehensive follow-up experiment by the same group of investigators was a study by Flexman, Matheny, & Brown (1950). They used the same School Link Trainer, blackboard, and cyclorama for initial practice of contact maneuvers by the experimental group, and again this ground training was followed by transfer to a light plane where the same maneuvers were performed. A control group practiced in the aircraft only. The same general use was made of the blackboard runway simulator as before, and the general conclusion of the study was that this use of the Link trainer and associated contact simulation equipment, crude though it was, gave positive transfer to the aircraft and deserved consideration for use in flight training programs. Subsequently, research for the Air Force by Flexman, Townsend, & Ornstein (1954), and Ornstein, Nichols, & Flexman (1954) again used the blackboard runway, but this time in conjunction with a P-1 simulator for the T-6 aircraft. The overall effect for a multi-faceted experimental training program, of which the blackboard runway was only a part, was positive transfer to the aircraft.

This preliminary work led University of Illinois investigators to examine more sophisticated techniques for visual simulation, and they concentrated their attention on the contact landing problem. Based upon a trigonometric analysis of landing by Bell (1951), the Aviation Psychology Laboratory of the University of Illinois developed a landing display for use with the SNJ OFT. This was a far more sophisticated device than anything used before because it was a closed-loop projection system where the runway image on the screen in front of the pilot changed dynamically, and automatically, with changes of the simulated aircraft with respect to the simulated runway position. The experimental design was the transfer of training design that was used in the other evaluation experiments discussed above, and six subjects were used in each of the two groups. The investigators concluded that contact simulation for the experimental group made a real difference in flying performance, and that an improved version of the contact landing attachment for the SNJ OFT should be assessed for operational Navy flight training.

Subsequently, a test of the University of Illinois contact landing display was made with naval aviation cadets by the U. S. Naval School of Aviation Medicine, Naval Air Station, Pensacola, Florida, and was performed and reported by Creelman (1955). The SNJ aircraft was being used as the aircraft for Navy primary flight training at that time, and an experimental program was inaugurated using the SNJ Link trainer, the University of Illinois contact landing display, and a cyclorama, to test their collective effectiveness in an actual operational flight training program. Creelman's experimental design was more sophisticated than previous ones. Not only did he strive for greater statistical sensitivity with 15 subjects in a group, but he also sought the source of the training contribution of the contact display. One group was a control group, one group was the traditional experimental group that received flight training in the SNJ Link trainer with contact landing simulation prior to flying the aircraft, and a third group was shown films of contact landings and the runway image simulated by the landing device, but no actual flying of simulated landings with the trainer and making the motor responses associated with specific runway configurations. This additional experimental group was control for the possibility that the value of the contact landing display was primarily perceptual, and had little to do with actually making the flight control responses in a closed-loop relationship with the display. Measurement of criterion performance in the aircraft was by instructor ratings. Creelman's general conclusion was that the group which actually flew the flight trainer with the contact landing display had distinctly superior landing performance in the overall training program, and this difference could not be accounted for by the intellectual training given the other experimental group. Creelman concluded that "This would indicate that the trainer's psycho-motor aspect was the key to the effectiveness of the procedure in contrast to the 'stimulus training' alone"(1955, p. 13). The transfer of training benefits over and above procedural and intellectual aspects of the landing task is a research issue that had been neglected in earlier investigations.

A Potential Role for Part-Task Simulation of Visual Cues

The transfer of training studies just discussed suggest a potential training value for closed-loop contact landing displays as an integral part of flight simulators. The vigorous developments in this area (Molnar & Lybrand, 1959a, 1959b) indicate that plans exist for eventual use of contact simulation devices in the training routines of operational flight training programs. But their use for routine operational training must be undertaken with full recognition of the complexity to be encountered. Many OFTs now in use by the Navy are trailerized to give them a mobility for maximizing their use in flight training programs, but this mobility certainly will have to be abandoned with the addition of elaborate electro-mechanical visual simulation subsystems to instrument OFTs. The size of these new visual simulators ordinarily will have to be large if a comprehensive range of cues is to be simulated, and this will mean fixed installations in airconditioned buildings. Moreover, initial costs of visual OFTs will be much higher, and there will be increased costs of supporting equipment and electronic maintenance personnel.

Two courses of action can be taken if the costs and operating difficulties of visual OFTs are considered too great. First, it simply could be concluded that training benefits are not worth the cost and the shortcomings of learning contact flying in aircraft are to be accepted. Secondly, it could be decided that training devices for contact cues are important but that research must find less expensive and less elaborate ways to structure the training equipment to achieve the same training goal. One possibility is a part-task trainer approach where some of the cues and controls for responses to them are abstracted from the totality of the task and embodied in a separate training device for specialized, intensive training use. This is contrasted to a whole-task simulator where an effort is made to closely approximate the characteristics of the parent aircraft and allow for practice of entire mission sequences. The defense of part-task trainers is that they are a less expensive way to achieve about the same training goal. For example, for the cues of contact landing an aircraft, it would be possible to present the runway cues for various types of landing problems on open-loop film and have the subject practice identifying the cues and perceptual relationships that he must know for successful landing while, concurrently, having flight control and procedures associated with contact landing learned in an instrument OFT. This combination of an OFT and a training film would be far less elaborate than an OFT with an integral closed-loop contact landing display, but whether the combination of an OFT and a film (or any other similar way of presenting complex visual patterns simply) can do the same training job as the total training device is a research matter that cannot be known a priori. The research that has been done on the effectiveness of part trainers shows that they can contribute substantially to enhancing certain flying skills but that they do have limitations (Adams, Hufford & Dunlop, 1960; Hufford & Adams, in press). This line of research has been performed on a part-task trainer called the "cockpit procedures trainer" which is a device designed to train specifically in the normal and emergency procedural sequences of an aircraft, quite apart from whatever requirements exist for concurrent aerodynamic flight control.

Several writers have discussed part trainers as having a possible shortcoming in their inability to provide for the learning of response time-sharing (Adams, 1957; DiVall, 1957; Dougherty, Houston, & Nicklas, 1957; Middleton, Allred, & Townsend, 1955; Muckler, Nygaard, O'Kelly, & Williams, 1959; Schohan, 1958). The time-sharing hypothesis holds that a part trainer has an inherent weakness for flight training because responses learned in it cannot be practiced in their appropriate time-shared relationships with other responses that occur in close time association with them. In other words, there are learned interactions between response classes, and these can be acquired only within the context of the total task where all response classes and their interactions are present. Practicing a particular response class in a part trainer can be beneficial but it cannot transfer 100 per cent to the whole task because the part trainer has not allowed for the learning of interactions. The time-sharing hypothesis was supported in an experiment by Adams, Hufford, & Dunlop (1960) when it was found that part training of aircraft procedures failed to give 100 per cent transfer to the total task, and that some supplementary whole-task practice was needed to attain an acceptable level of proficiency. A subsequent study by Hufford & Adams (in press) found a similar weakness for cockpit procedures trainers in the relearning of aircraft procedures forgotten over a retention interval of 10 months.

Time-sharing is an empirical characteristic of responses in complex tasks that must be proved by experiment, and at present there is no way of estimating whether any particular method of part training will be less than fully satisfactory because of it. The use of a part training device for contact landing, such as a film where the subject learns the complex patterning of cues associated with correct and incorrect landing patterns, may or may not suffer from being isolated for separate study. A possibility for time-sharing exists in the requirement for a pilot to interpret the contact world perceptually and evaluate the relationship of his aircraft to the runway while, at the same time, cross-checking his instrument panel to verify that he is holding proper airspeed, heading, vertical speed, etc. Training perceptual judgments and instrument flying separately will not allow for the learning of this time-sharing involved in the visual scanning of contact and instrument panel cues, and additional practice in the whole flying task might be considered as necessary for attaining a satisfactory level of performance.

On the other hand, we might hypothesize that visual scanning as the basis for time-sharing is trivial for practical flight training and that the problem is not so much one of time-sharing as it is of learning to identify errors in the visual scene and the flight control responses necessary to eliminate them. Flying an aircraft is a multi-dimensional tracking task, and it cannot be conceived as a simple motor skill. Rather, the behavior can be conceptualized as more complex in the sense of having mediating perceptual and/or implicit verbal cues that are elicited by the external stimuli, and these internal sources of discriminative stimuli become a critical part of the total cue complex that guide the corrective action of the tracking responses. Not all tracking need be mediated as we have implied here. Ordinarily tracking is thought to be a continuous error-nulling process with no concern for mediation, but there has been recent evidence for mediating responses in tracking (Adams, in press; Adams & Creamer, in press; Poulton, 1952a, 1952b, 1957; Vince, 1953, 1955). For simple tasks, perceptual-verbal pretraining often has been found to be beneficial, and is reported in the psychological literature under the headings of stimulus predifferentiation, verbal pretraining, or perceptual learning. The research under these rubrics is reviewed in papers by Goss (1955), Arnoult (1957), Kanfer (1956), and Vanderplas (1958). Perceptual-verbal pretraining for contact landing with a simple device like a film may be expected to transfer positively to the total landing task because the mediating responses associated with correct and incorrect visual patterns would be strengthened in part-task practice and would be reflected in increased proficiency when the total task is performed.

It is difficult to say what advantages might be expected from the perceptual-verbal pretraining of contact landing patterns where at various points in the landing sequence the pilot would be asked to identify the presence or absence of an error, and specify the error's nature and cause, if one is present. The positive results that have been reported for perceptual-verbal pretraining are situations where a subject in pretraining learns identifying verbal labeling responses for static stimuli, and this pretraining is shown to aid him subsequently in identifying the stimuli in a discrimination task, or in making selective, discrete motor responses to the stimuli. The multi-dimensional tracking task of flying an aircraft throughout a contact landing pattern is so much more complex than the laboratory tasks used for this line of research that it is difficult to make an unequivocal prediction of the outcome of perceptual-verbal pretraining for contact landing patterns. The runway display has much greater complexity, not only because it requires the evaluation of a form with respect to a learned standard, but also because it requires this evaluation under conditions of dynamic movement of the runway image where movement patterns and their rates can be significant for the judgment. And, another important difference is that the task is one of error discrimination and continuous tracking corrections, where the pilot must discriminate an error from the normative pattern he has learned, determine its nature, and follow this mediating process with a corrective motor tracking response. It would appear that while both the visual landing display and response sequences to it are much more elaborate than those studied in the usual laboratory experiment of perceptual-verbal pretraining, the behaviors can be regarded as having processes in common, and positive transfer to the whole flying task might reasonably be expected from the non-motor perceptual pretraining of evaluating landing display patterns. There is little to guide an experiment such as this, and to inform us on the nature and amount of pretraining judgments that should be made, but the engineering complexities and cost of closed-loop visual simulation attachments for flight simulators represent such a change from existing training equipment that experiments on new, simpler techniques of training these skills seem justified. If positive benefits can be found for perceptual-verbal pretraining, it would suggest important lines of development for visual part-trainers that would be a simplified equipment training package to produce about the same training yields.

The laboratory research to be reported here represents an attempt to show positive effects of perceptual-verbal pretraining for contact landing a simulated aircraft. The experiment was performed with the Contact Analogue Landing Research Tool, which is a research device having a runway display in closed-loop conjunction with a flight trainer to provide simulation of night landings. The entire experiment was conducted with this device, and the pretraining was given by programmed sequences of the trainer's visual display where the subject was required to make judgments about correct and incorrect landing patterns presented to him, but was not required to fly the simulated aircraft. The transfer criterion performance was measured when the subject actually flew simulated contact landings with the flight trainer, using the system as a whole. Comparison was with control subjects that were not given perceptual pretraining exercises.

EXPERIMENTAL METHOD

Research Equipment

1-CA-1 Link Trainer. As will be discussed subsequently, the use of naive subjects for studying the basic perceptual-motor learning process required the teaching of flying fundamentals, and a Link 1-CA-1 Basic Instrument Trainer was used to teach them the essentials of controlling an aircraft under instrument flying conditions. Two hours of practice were given in this trainer prior to flying simulated contact landings in the Contact Analogue Landing Research Tool. This was not the same trainer unit that served as a primary component of the Contact Analogue Landing Research Tool, but it was the same type and had the same flying characteristics, so it was considered a satisfactory instrument for the training job.

Contact Analogue Landing Research Tool (Device 20-L-10a). This device was the central research instrument of the research program, and was delivered to the Aviation Psychology Laboratory, University of Illinois, after being developed by Reflectone Electronics, Inc., Stamford, Connecticut, under the direction of the U. S. Naval Training Device Center. Figure 1 shows a cross-sectional drawing of the Contact Analogue Landing Research Tool (hereafter called the Contact Landing Trainer). The overall size of the device is 12 feet high, 27 feet long, and 11 feet wide. Figure 2 is a drawing of representative scenes of the night landing problem that is simulated. A cyclorama surrounds the trainer and is painted black to increase the fidelity of simulating a night landing.

The method of runway image simulation is point-source projection where a mercury lamp and an optical system shine a light beam through a runway slot which is part of a movable card. The light passing through

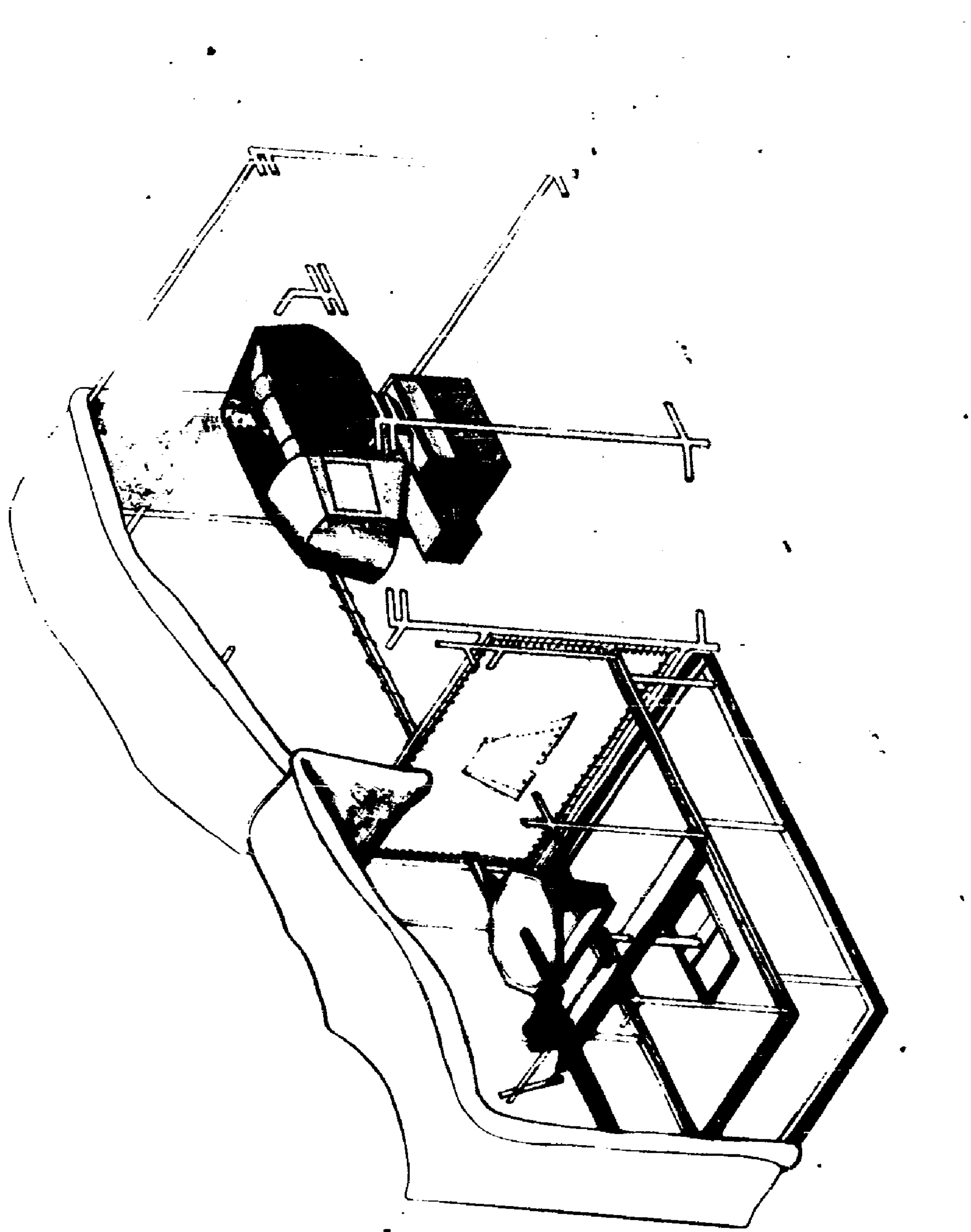

Fig. 1. Cross-sectional view of the Contact Analogue Landing Research Tool that was used as the principal research device.

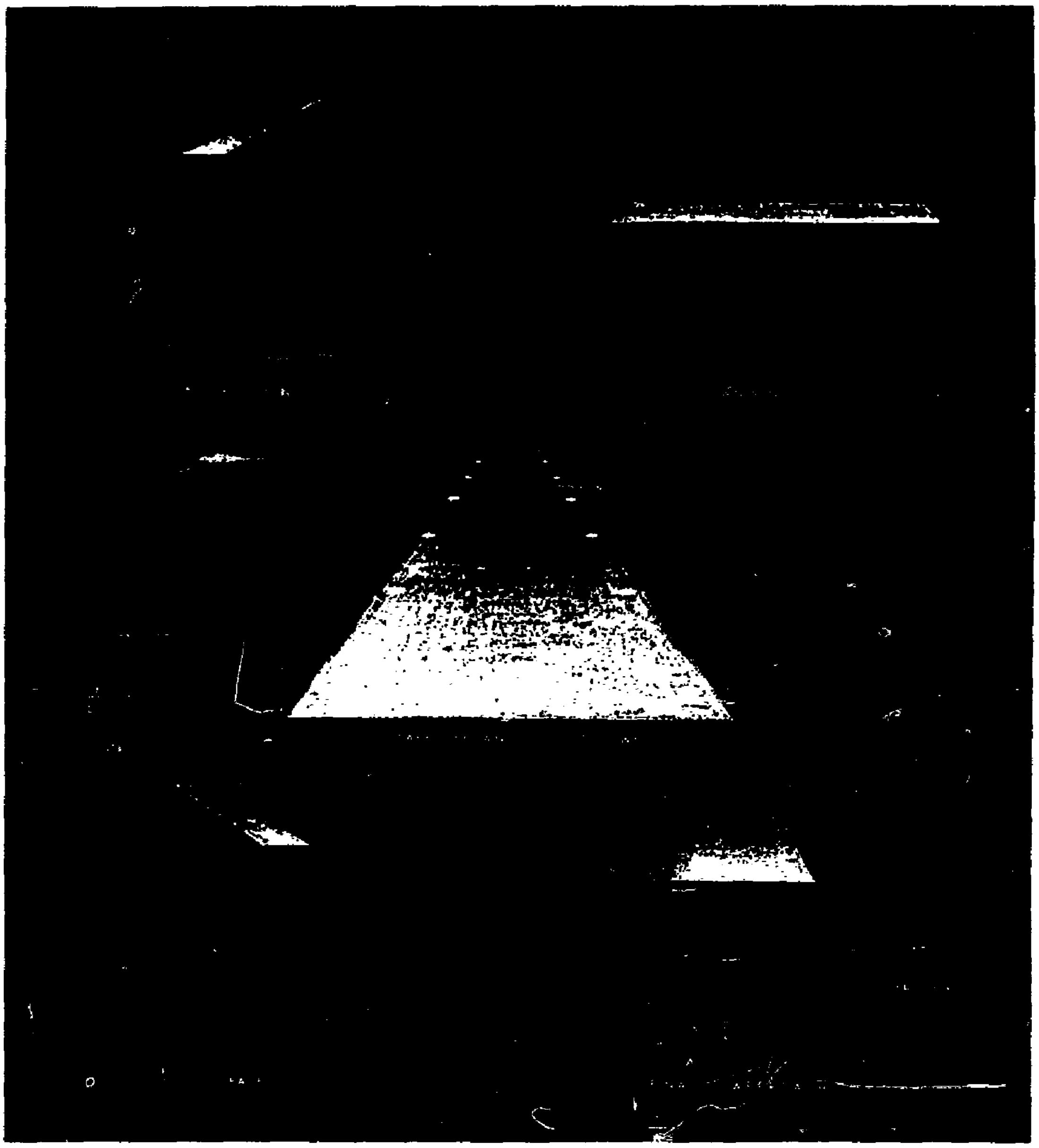

Fig. 2. Representative scenes of the runway image for the night landing problem simulated by the Contact Analogue Landing Research Tool.

the slot appears as the runway image on the rear of a translucent screen and is seen by the subject on the opposite side of the screen. The system is closed loop, and the pilot flies a Link 1-CA-1 Trainer in relation to the runway image in the same fashion as he would fly an actual aircraft with respect to a real runway. The trainer is flown to achieve the proper aircraft-image relationship, and the trainer outputs of airspeed, heading, and altitude go to computers which, in turn, position the runway card and change the projected image in accordance with the pilot's flying of the simulated aircraft. This closed-loop computing process is continuous as the aircraft position keeps changing with respect to the runway.

The heart of the simulation technique is a runway card that is in a moving mechanism positioned in three dimensions by servo motors. The three dimensions correspond to the range of the aircraft from the runway, the altitude of the aircraft, and the bearing or angular relationship of the aircraft with respect to the runway. As the pilot flies and positions the aircraft in these three dimensions, the three-dimensional mechanism moves the runway card a given horizontal distance from the light source (range), a given vertical distance with respect to the light (altitude), and rotates the card for the bearing of the aircraft to the runway. Flying the aircraft in the simulated ground-air space around the runway actually moves the runway card in three dimensions, and the continuously changing image gives the pilot the rather compelling illusion that he is moving in relation to a fixed runway. In actuality the simulation scheme is just the converse because he is flying the runway card in relation to a fixed Link trainer.

The computer model for the system has a North-South runway that is 200 feet wide and 3500 feet long. The system is scaled so the pilot can fly anywhere within a 10,900 feet radius from the North end of the runway (which is the electronic center of the simulation), from zero to 3200 feet of altitude, and throughout 360 degrees of bearing. The pilot can take off from the runway, fly in any direction out to 10,900 feet from the North end of the runway, maintain an altitude anywhere from zero to 3200 feet, and then return to the runway and land. Throughout the flying in this simulated air space the runway image maintains a size, shape, and angular orientation that is deemed appropriate by the computations of the system. A normal airspeed is 110 MPH, and vertical speed should not exceed 2000 feet per minute.

The system has what we term "slaving properties" that function to produce poor simulation very temporarily after takeoff. Slaving becomes a necessary property of the system to simulate the runway being in front of the pilot as he proceeds on his takeoff roll and, when he becomes airborne, to place the runway behind him as he holds his takeoff heading on the climb out. At the start of a takeoff in the Contact Landing Trainer the pilot sits in the trainer facing the screen and the runway image spreads out in front of him. Power is applied, the aircraft begins its roll down the runway, and the runway image begins moving rather rapidly and appears to pass beneath the trainer. As the aircraft passes over the North end of the runway, the runway should begin to appear behind the pilot, but without slaving the Contact Landing Trainer would still be facing the screen as the pilot continues on his takeoff heading. The design problem was one of orienting the trainer so the pilot has the screen behind him on climb out. Slaving accomplishes this need for a change in trainer-screen orientation by a powered movement of the entire trainer throughout 180 degrees, at a rate of about 15 degrees a second. The movement is completely unrealistic, but it is over quickly and the pilot continues his heading and climb throughout this brief but sharp maneuver. This 180-degree slaving action is the only noticeable instance of slaving, although slaving is present throughout flying as a means of maintaining the proper angular relationship between runway and aircraft. However, with the exception of the 180-degree rotation, slaving is so gradual that it passes undetected. The 180-degree slaving is sidestepped in research by allowing the system to stabilize after slaving before measures of flying proficiency are taken. Cockpit instrument readings are not influenced by slaving.

The Recording of Flying Proficiency. The ground track of the simulated aircraft in relation to the runway was recorded on an X-Y plotter with a scale of one inch equals 1000 feet. Reading accuracy of the X-Y chart records was to 50 feet. Altitude was recorded simultaneously on a separate Esterline-Angus Recorder, and the record was read to an accuracy of 25 feet. The pens of both recorders were pulsed every 10 seconds, allowing time synchronization of the two performance records.

The Experimenter had repeater flight instruments at his console as part of the means of giving the subject knowledge of results about his flying proficiency. The instruments were airspeed indicator, altimeter, vertical speed indicator, heading indicator, and manifold pressure gauge. Except for a bank indicator, these were the same instruments as in the Contact Landing Trainer.

<u>System Programmer</u>. Perceptual-verbal pretraining for the Experimental Group required a method of exposing the subject to correct and incorrect landing patterns so he could come to identify the characteristics of the runway image when an error was present, and to verbalize the occurrence of an error and its cause. Moreover, we considered it to be useful pretraining if the landing pattern continued to its termination after the error so the subject could see what an error meant for the totality of the landing pattern if left uncorrected. To accomplish this we built a System Programmer that automatically flew the Contact Landing Trainer throughout a landing pattern from takeoff to touchdown, with or without an error, and the subject could observe and concern himself solely with the task of perceptual evaluation. No control inputs were required of the subject during a programmed landing pattern.

The System Programmer generated left-handed landing patterns. The simulated flight started at the South end of the runway and the beginning of the automatic flight was with the roll of the aircraft down the runway on a heading of 360. When the plane reached the end of the runway a climb was begun at the rate of 600 feet per minute. At an altitude of 400 feet a turn was made to a heading of 270 degrees, which was the Crosswind Leg. The rate of climb was held until an altitude of 900 feet was reached. At a defined point the turn was made to 180 degrees, and this positioned the aircraft on the Downwind Leg. The flight was continued on this heading until the aircraft was about two-thirds down the runway, at which point a descent of 600 feet per minute was initiated. The descent continued and, near the end of the Downwind Leg, a turn to heading 090 was made which placed the aircraft on the Base Leg of the pattern. This heading was continued until the turn to heading 360--the Final Leg. Descent continued until touchdown. The programmer then continued to fly the system and take the subject through another pattern (set in by the Experimenter), just as if he was flying touch-and-go landings.

The System Programmer was designed to fly the system through a normal pattern or any one of eight error patterns. The error patterns were early and late turn to Downwind Leg, early and late turn to Base Leg, early and late turn to Final Leg, and early and late times of starting the descent. The specifications for each pattern are given in Table 1. An error remained uncorrected after its programmed occurrence, and this feature allowed the subject to see the consequences of an error develop with time, and what the error meant for the termination of the landing if left uncorrected.

Experimental Design

General Plan. Table 2 shows the design of the experiment, where the two groups differed only in the perceptual-verbal pretraining exercises administered to the Experimental Group with the System Programmer. Table 2 indicates that a considerable portion of time was devoted to teaching naive subjects the principles of flight and preparing them for the relatively complex task of flying the Contact Landing Trainer in the final two criterion sessions. The additional burden of teaching naive subjects was shouldered because it was assumed that a larger effect would be observed for perceptual-verbal pretraining if the learning process was studied from the beginning. The criterion sessions provided measures for comparing the effects of experimental treatment, and a total of 27 criterion landing problems were flown.

The detailed procedures for each phase of the experiment will be discussed below.

TABLE 1

Characteristics of the nine different landing problems automatically sequenced by the System Programmer. The pattern is always left-handed. The North end of the runway is the point of reference for measuring the distance of the Crosswind and Base legs. Downwind and Final are referenced with respect to the runway centerline. Aircraft heading at takeoff is North. Airspeed is 110 MPH, and vertical speed is 600 feet per minute during ascent and descent.

	Distance (feet)				Altitude (feet)				
Landing Pattern	Crosswind Leg	Downwind Leg	Base Leg	Final Leg	Downwind Turn	Base Turn	Final Turn	Over End of Runway	Landing Termination
Normal	4800	4750	7000	0	900	725	400	0	Lands at end of Runway
Early turn to Downwind Leg	4800	3750	7000	0	900	725	480	80	Lands 1000 feet down runway
Late turn to Downwind Leg	4800	5750	7000	0	900	725	320	---	Lands 1000 feet short of runway
Early Descent	4800	4750	7000	0	900	645	320	---	Lands 1000 feet short of runway
Late Descent	4800	4750	7000	0	900	805	480	80	Lands 1000 feet down runway
Early turn to Base Leg	4800	4750	6000	0	900	805	480	160	Lands 2000 feet down runway
Late turn to Base Leg	4800	4750	8000	0	900	645	320	---	Lands 2000 feet short of runway
Early turn to Final Leg	4800	4750	7000	500 feet West of Centerline	900	725	440	40 (when opposite end of runway)	Lands 500 feet down runway and 500 feet West of centerline
Late turn to Final Leg	4800	4750	7000	500 feet East of Centerline	900	725	360	---	Lands 500 feet short of runway and 500 feet east of centerline

TABLE 2

Experimental design for examining the role of perceptual-verbal pretraining in learning to perform simulated landings in the Contact Landing Trainer. The use of non-pilot subjects required basic training in the principles of flight. A whole-task criterion problem is the flying of a complete landing pattern from takeoff to touchdown

Laboratory Period No.	1	2	3	4	5	6
Group					(Criterion Session I)	(Criterion Session II)
Experimental	Classroom training in the principles of flight. 2 hours.	Basic flight control and instrument flying in 1-CA-1 Link Trainer. 1 hour.	Instrument flying of landing pattern in 1-CA-1 Link Trainer. 1 hour.	Contact landing film. Discussion of landing errors. 16 programmed landing problems in Contact Landing Trainer. 1 hour.	Three whole-task landing problems for familiarization. 12 whole-task criterion problems for record. 1 hour.	15 whole-task criterion problems for record. 1 hour.
Control	Same	Same	Same	None	Contact Landing film. Discussion of landing errors. Three whole-task landing problems for practice. 12 whole-task criterion problems for record. 1 hour.	Same

Classroom Training. All subjects were given a common classroom training curriculum on the principles of flight. The two-hour lecture was given a number of times to subgroups of 3-5 subjects so that they could immediately begin the next phases of the program without delay. The lecture included excerpts from Navy Film No. NM3474D on the fundamentals of flying, and prepared lecture materials on aerodynamics, flight control, flight instruments, and power management. A mockup of the flight instruments was used as a training aid, where the indicant of each instrument was movable by the Experimenter for illustrative purposes. In the latter part of the period the Experimenter flew the 1-CA-1 Link Trainer for the subjects to illustrate flight control principles and the actions of flight instruments.

Basic Practice of Instrument Flying. On a following day each subject returned to the laboratory and was given individual instruction in flying the 1-CA-1 Link Trainer. The session was an under-the-hood instrument flight. Conventional maneuvers were practiced, such as straight and level flying, climbs, dives, and turns. The importance of power control and the use of trim tabs were emphasized as fundamental for good flight control. Other instructional emphases included instrument lag characteristics, and the interaction of flight dimensions such as the need for stick back pressure to avoid altitude loss in a turn. No mention was made of contact landing in this period.

Basic Practice of Landing Pattern Regime. The second session in the 1-CA-1 Link Trainer on a different day was concerned with the procedures and instrument flying requirements for a landing pattern. The normal landing pattern, and the values of the flight parameters, closely approximated those that would be used with an SNJ aircraft.

The subject repeatedly practiced a left-handed traffic pattern from takeoff to landing. The start of the maneuver required the subject to hold the aircraft at zero altitude on a heading of 360 with power setting of 22 inches. Power was increased to 32 inches for the takeoff roll and a climb of 600 feet per minute was initiated with the airspeed being held at 110 MPH. At an altitude of 600 feet the subject was instructed to turn left to a heading of 270 and continue to climb to 900 feet, where the aircraft was to be leveled off with a power setting of 22 inches and an airspeed of 110 MPH. The subject then was instructed to turn left again to a heading of 180, still holding 900 feet of altitude. The descent phase of the landing was next begun where power was reduced to 17 inches, airspeed held at 110 MPH, and rate of descent set at 600 feet per minute. At about 650 feet he was told to turn left to a heading of 090 and continue the descent. At 300 feet he was directed to turn onto the final approach heading of 360 and continue to fly on down to zero altitude. When zero altitude was reached the subject was directed in the various adjustments of the trainer's flight parameters to ready it for the next pattern.

Full knowledge of results was given by the Experimenter at all times so the subject was always fully aware of his errors and what he should do to correct them. Legs of the pattern were identified for the subject. Depending on the subject's progress, seven or eight patterns were completed in the second Link Trainer session.

Contact Landing Film. Up until this time the subject had not been exposed to the characteristics of the visual runway scene throughout a contact landing sequence. To give him basic familiarization, a film was produced to show changing visual characteristics of the runway during correct and incorrect landing patterns. An SNJ aircraft was used to fly the different landing patterns that were photographed by a cameraman passenger. Each photographed landing pattern had a series of representative shots of the runway at takeoff, and during the Crosswind, Downwind, Base, and Final Legs. The film consisted of the following patterns:

1. Normal pattern as we defined it for our subjects in the experiment and as we instrumented in the System Programmer.
2. Late turn onto the Downwind Leg.
3. Early turn onto the Downwind Leg.
4. Late turn onto the Base Leg.
5. Early turn onto the Base Leg.
6. Final approaches:
    a. Normal.
    b. Too high.

c. Too low.

d. Effects of early and late turns onto the Final Leg that place the aircraft to the right or left of the runway centerline.

The Experimenter accompanied each of these filmed landing sequences with explanatory remarks. The showing of the film was followed by a discussion of various types of landing errors and their consequences. For example, the Experimenter would ask how an early turn onto the Base Leg would influence the altitude on the final approach (too high). The film and the discussion were in the same period as the perceptual-verbal pretraining problems for the Experimental Group, and at the beginning of the first criterion session for the Control Group. In both cases they immediately preceded the subject's first acquaintance with the Contact Landing Trainer.

Perceptual-Verbal Pretraining for the Experimental Group. Following the contact landing film and the discussion of landing errors, the subjects of the Experimental Group were placed in the Contact Landing Trainer and the System Programmer was used to fly them automatically through 16 landing patterns. Each of the eight error patterns was given once, and eight normal patterns were mixed with the eight error patterns. The first two patterns were normal patterns. Eight normal patterns were included in an attempt to insure the learning of a standard of correctness when a discrimination and judgment of a displayed runway configuration was made.

During the 16 problems, the subject was required to judge the presence or absence of an error 46 times. If the error was present and he identified it, he was asked to indicate its type (e.g., too high) and its initiating cause (e.g., early turn to Base Leg). The Experimenter gave full knowledge of results each time.

Appendix A has five example data sheets that were used by the Experimenter. Scoring was in terms of errors. To illustrate, consider Data Sheet No. 3 in Appendix A for a programmed error of late turn onto Final Leg. On the Base Leg, before the error occurred, the subject was asked if the pattern was correct. If he said "No" he was scored zero error, and if he said "Yes" he was scored three because he mistakenly judged a correct display, and because he also would have been wrong when he responded to the type of error and its cause. Thus, there were three wrong judgments implicit in his misjudgment of a correct configuration of the image, and we assigned an error score of three. But when he was asked to judge a true error on the Final Leg, the error score could range from zero to three. The score was zero if he correctly identified the presence of an error, its nature, and its cause. If the subject failed to identify the presence of an error at all, his score was three. On occasion a subject would be partly correct, and would be assigned a score of one or two. From these scores we were able to compute group percentage of total possible error score for correct and for error patterns, and for the several legs of the pattern.

Subjects were dark-adapted for fifteen minutes before beginning the programmed patterns. A five-minute rest was given between Patterns 8 and 9.

Familiarization in Flying the Contact Landing Trainer. All subjects were given three familiarization trials in the Contact Landing Trainer to insure that they grasped the fundamentals of the task before the criterion patterns were flown for record. During these trials the Experimenter freely used the intercom in explaining procedures. After a complete landing sequence, full knowledge of results were given as the subject was climbing out and entering the Crosswind Leg of the next pattern. Fifteen minutes of dark adaptation preceded the first trial.

Criterion Sessions in the Contact Landing Trainer. The culmination of all the previous training was in two criterion sessions where a total of 27 landing patterns was flown to provide criterion measures for the experimental comparisons. Twelve of the trials were in the first session, and 15 in the second. The patterns were flown continuously, as in touch-and-go landings. Left-hand patterns were flown. Headings, airspeed, vertical speed, altitude, etc., for a pattern were the same as practiced earlier in the 1-CA-1 Link Trainer.

The Experimenter gave knowledge of results over the intercom when a pattern had just been completed and the subject was climbing out on the next pattern. The work load required that a second Experimenter be used for monitoring the recording equipment. Fifteen minutes of dark adaptation preceded each session.

Subjects

Four pre-experimental subjects were processed through the entire experimental program to test the methods and techniques that had been devised. The main experiment had 30 male university students as subjects, 15 in each group. Except for being aircraft passengers, all were naive with respect to flying. They were paid for their participation.

Experimenters

Mr. Lyle E. Hufford was Project Leader of the study and was the principal Experimenter. He was a graduate student in engineering psychology, and his background included military jet flying and flight instructing. Mr. Hufford conducted the classroom training, the basic flight training in the 1-CA-1 Link Flight Trainer, and the criterion sessions in the Contact Landing Trainer.

Other research assistants assisted in preparing experimental materials, data collection, and data analysis. They were graduate students in engineering psychology.

Supplementary Data From Experienced Pilots

Eight experienced professional pilots flew 12 landing patterns in the Contact Landing Trainer. These data were outside the interests of the main experiment but it was thought that the results would serve useful informational purposes on flying behavior in the new Contact Landing Trainer and could be compared profitably with the performances of the naive subjects.

All were current pilots with flying time in excess of 2000 hours. They were either Air Force officers serving as ROTC instructors at the University of Illinois, civilian flight instructors at the Institute of Aviation of the University of Illinois, or commercial pilots.

RESULTS

Perceptual-Verbal Pretraining

After classroom training and before flying the Contact Landing Trainer, the Experimental Group was given 16 representative landing patterns with the System Programmer. The subject was automatically flown through a landing sequence, and his sole task was perceptual evaluation of the display and to reply to the Experimenter's request for evaluation of the display. A total of 46 judgments were elicited from the subject, and the Experimenter gave knowledge of results each time. The transfer value of this part-task pretraining to the whole-task flying of the Contact Landing Trainer will be discussed subsequently, but performance on the pretraining problems themselves provide the opportunity to assess the comparative difficulty that subjects experience in evaluating various correct and incorrect configurations of the contact landing display.

Table 3 shows for each leg of the pattern the per cent of total possible errors when the landing pattern was either correct or incorrect. No errors were presented on the Crosswind Leg. Total possible error, as the baseline for the percentage, means that if all subjects had completely missed all parts of all judgments required on a leg, then per cent of total possible error score for the group would be 100%. Table 3 shows that performance was good when there was no error in the landing pattern at the moment of judgment, with the level of error running about 15%. However, the right-hand column of Table 3 shows that the discrimination of a true error is relatively poor, with particularly poor performance on the Downwind Leg. Very commonly, the presence of an error could not be discriminated on the Downwind Leg even though the aircraft was flying 1000 feet from the desired position. The Base Leg

TABLE 3

Per Cent of Total Possible Error Score for Judgments Required of the Experimental Group at Points Where the Displayed Pattern was Either Correct or Incorrect

Leg	No Error Present in Display	Error Present In Display
Crosswind	15	----
Downwind	17	63
Base	14	41
Final	16	15

Note:--No incorrect sequences of the pattern were programmed on the Crosswind Leg. All types of programmed display errors and judgments are pooled.

also shows moderately poor error interpretation, but judgments on the Final Leg are at an acceptable level. Good discrimination of error on the final approach is understandable because the image distortions for wrong approaches, particularly when the aircraft is to the right or left of the desired glidepath, are obvious.

Table 4 is a breakdown of all wrong responses for the Downwind, Base, and Final Legs. The per cent of total possible error is based on a separate total error score for each of 18 categories in the table. Table 4 is broken down into the type of judgment required for an error on a leg, and whether the error was one of spatial displacement of the aircraft from its correct flying path, or of time where the descent was begun either too early or too late. The left-hand column of Table 4 shows the results for spatial error and the assessment of error on Downwind is again shown to be difficult. Less difficulty was encountered for spatial errors on the Base and Final Legs. In the right-hand column of Table 4 all evaluations of the display were missed when the programmed error was in the time of initiating descent. However, when the time error problem reached the Final Leg, the nature of the error apparently had become sufficiently prominent to decrease sharply the level of error. Only seven per cent of the error determinations on Final were wrong, but subjects were somewhat less successful in discerning the nature of the error or its basic cause.

TABLE 4

Analysis of Wrong Judgments by the Experimental Group Made in the Perceptual-Verbal Pretraining Patterns. Entry is Per Cent of Total Possible Error Score for the Category Indicated

Leg		Displayed Errors of Spacial Dis- placement	Displayed Errors in Time of Starting Descent
	Determination of Error:	40	100
Downwind	Nature of Error:	50	100
	Cause of Error:	43	100
	Determination of Error:	10	100
Base	Nature of Error:	13	100
	Cause of Error:	10	100
	Determination of Error:	10	7
Final	Nature of Error:	16	13
	'ause of Error:	22	20

Spatial E.-

Measurement. The recording pen of the X-Y Plotter was pulsed every 10 seconds and this point was used for measuring the discrepancy between the actual pattern and the one we taught the subjects as normal or desired. The normal pattern is defined in Table 1 where its specifications were included in the system programmer. The error deviation of the actual from the normal pattern on the chart record was measured in feet, and the score for a subject on a leg was algebraic mean of the error deviations taken at each 10-second interval. Because of the slaving characteristics of the system, simulation on the Crosswind Leg was considered poor and consequently no measures of flying proficiency were made in that portion of the pattern. In addition to a score for the

Downwind, Base, and Final Leg, a total error score was computed for a subject as the mean error deviation for all three legs combined. To prevent the slaving action of the trainer from disturbing the subject and causing him to make a biasing spatial error that might persist throughout the pattern, the X-Y recorder was always zeroed to the correct spatial position for the normal pattern after the 180-degree slaving was completed.

Figure 3 shows the convention for error measurement and algebraic sign. When error exceeded the bounds of the ideal pattern it was positive, and when it was within the ideal pattern it was negative. Both absolute error and algebraic spatial error are tabled in Tables 7 through 12 in Appendix B. The basic data analysis and interpretations are presented in terms of absolute error.

Results. Figures 4, 5, 6, and 7 show the plots of mean absolute spatial error for each group as a function of blocks of three trials. The curves show a distinctive learning effect. The level of error on the Downwind Leg in Figure 4 is higher throughout than for the Base and Final Legs, and this supports the findings for perceptual-verbal pretraining showing that judgment of error was most difficult on the Downwind Leg. Accuracv in spatial alignment with respect to the runway is most accurate of all on Final, with performance on the Base Leg having an intermediate error level, and this tendency is supported in the perceptual pretraining findings also.

Tables 9 and 10 in Appendix B give the mean algebraic error of the same data that are presented in Figures 4 through 7 as absolute error. The average tendency for algebraic scores is to be positive in sign, signifying a consistent tendency to fly patterns wider than the normal.

Using the absolute error score on a block of three trials as the score for the subject, a Type I analysis of variance (Lindquist, 1953) was performed on each set of the two learning curves of Session I presented in Figures 4 through 7. Table 5 gives the results of these four analyses of variance. Part-task perceptual-verbal pretraining for the Experimental Group apparently had no transfer effect to whole-task flying of the Contact Landing Trainer because in each instance the

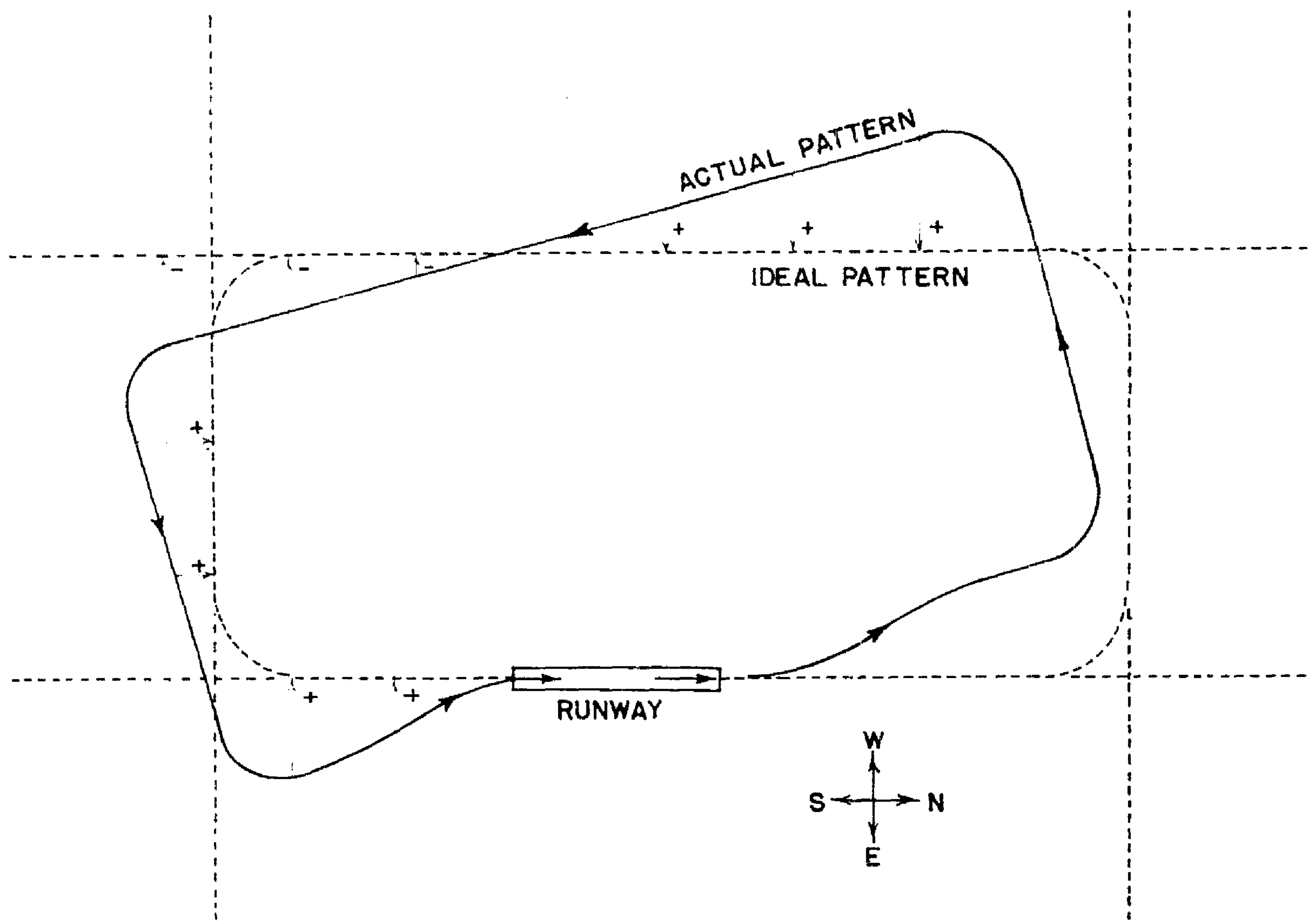

Fig. 3. Schema for measuring spatial error as deviation of the actual ground track of a landing pattern from a normal or ideal pattern. The algebraic convention for measurement is shown.

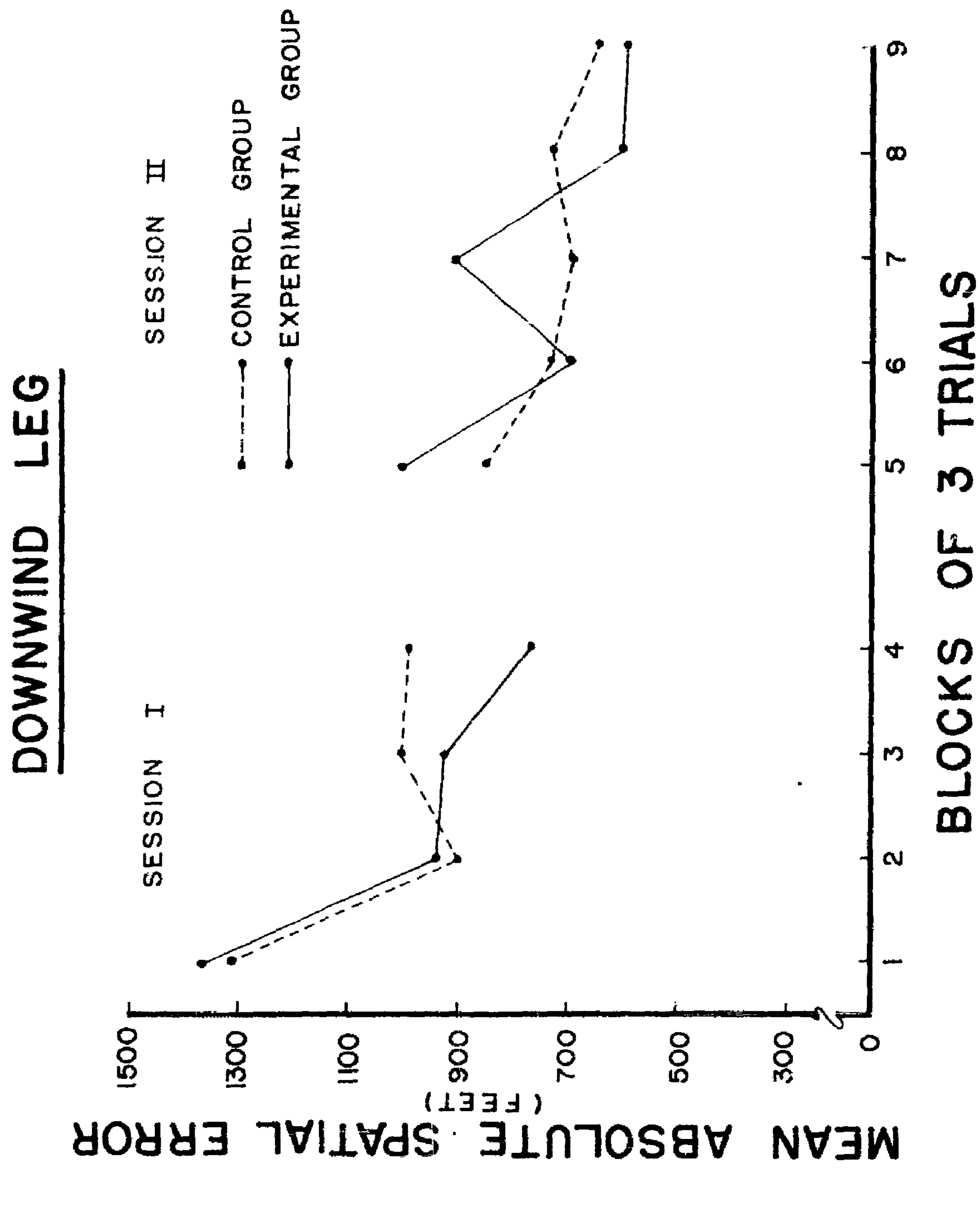

Fig. 4. Mean absolute spatial error on the Downwind Leg.

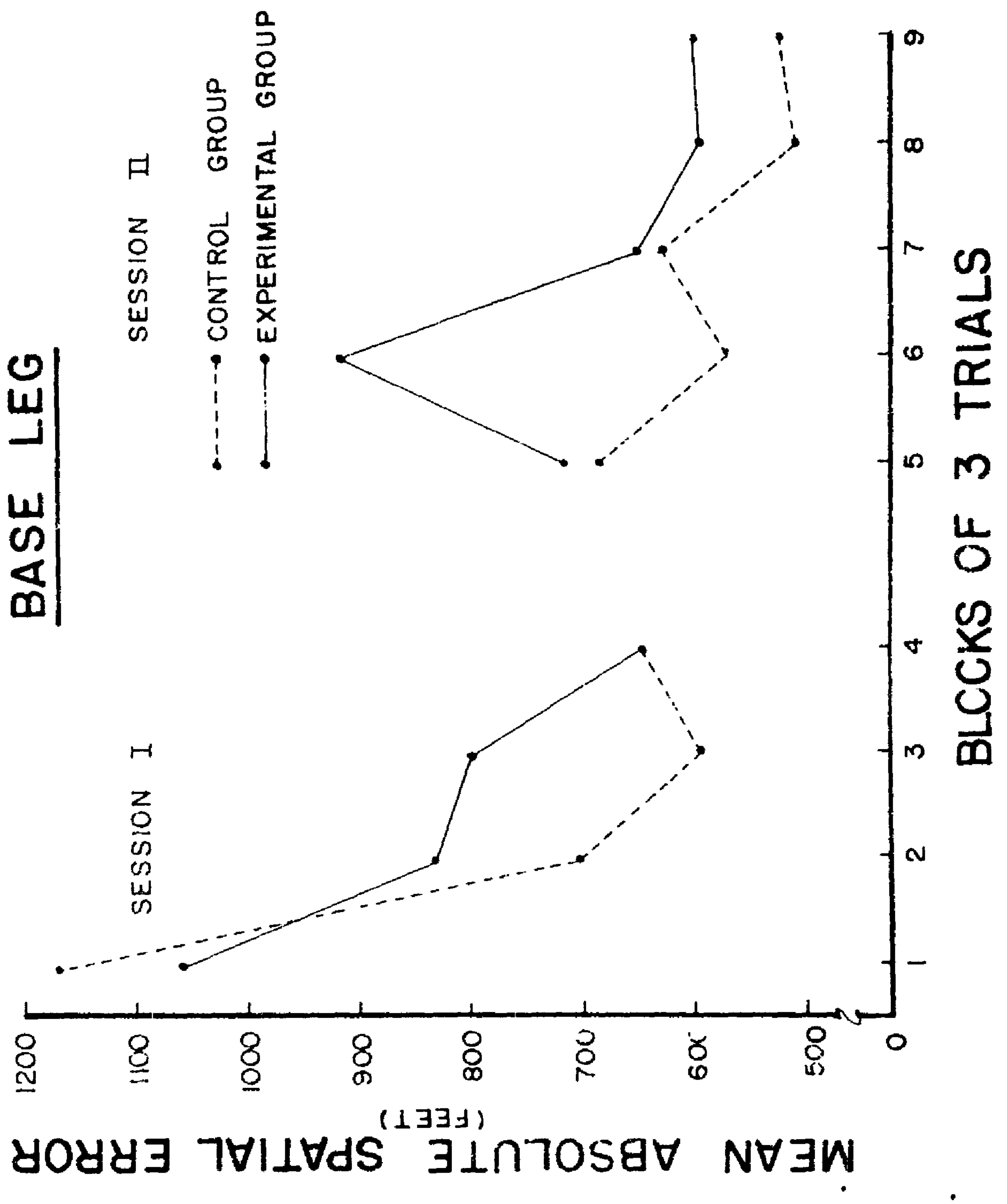

Fig. 5. Mean absolute spatial error on the Base Leg.

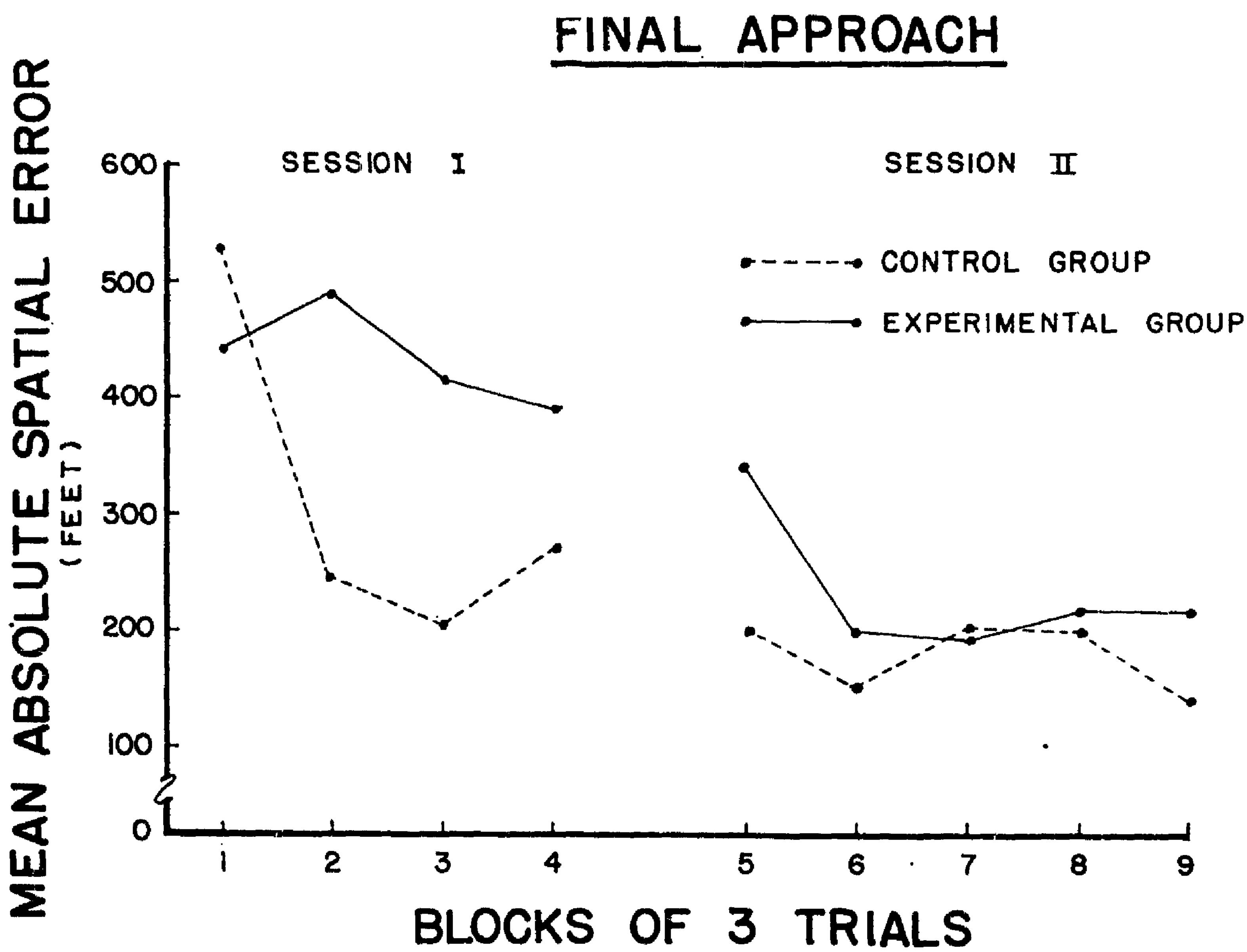

Fig. 6. Mean absolute spatial error on the Final Leg.

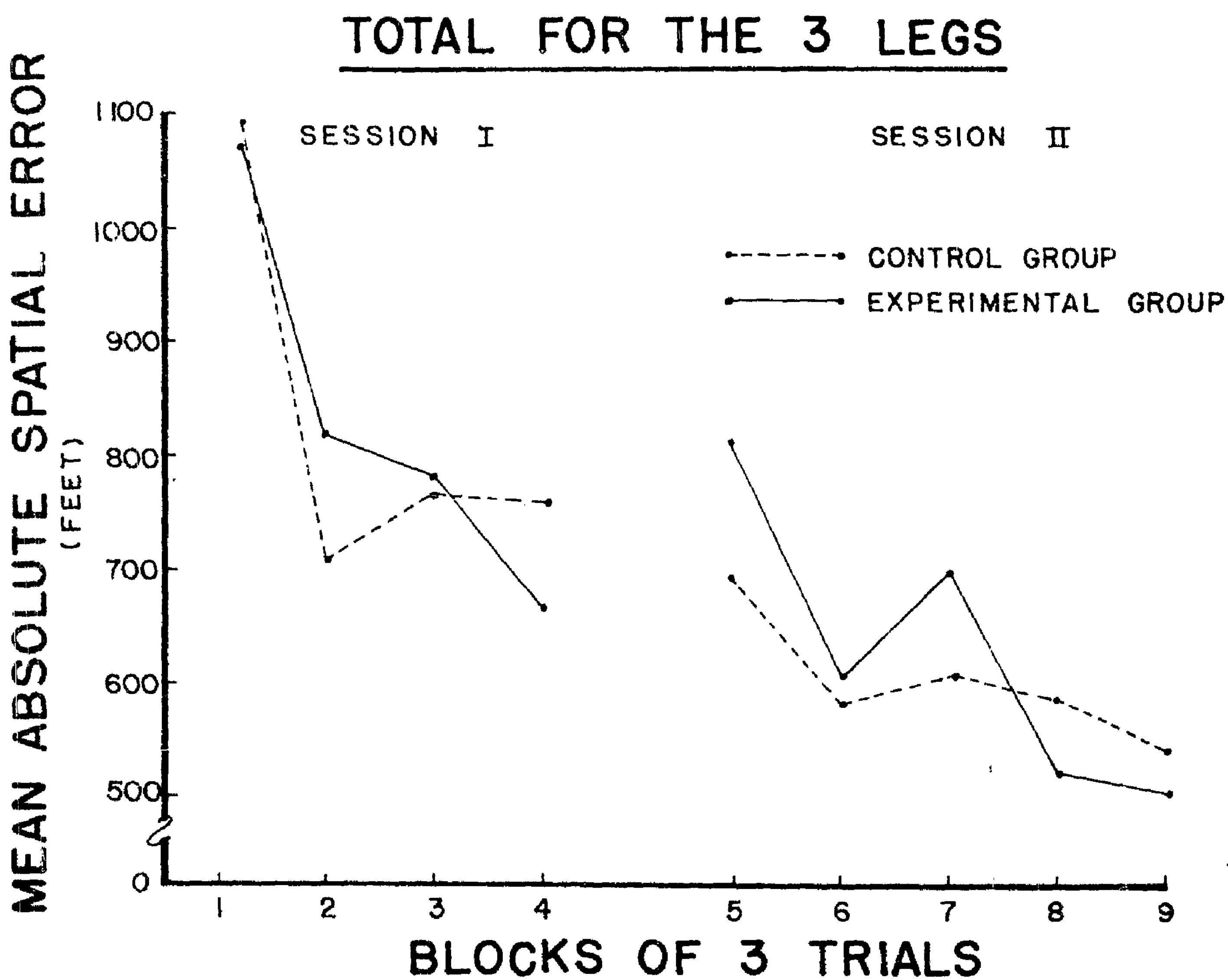

Fig. 7. Mean total absolute spatial error, where the score for a subject was spatial error summated over Downwind, Base, and Final legs of the pattern.

TABLE 5

Results of Type I Analyses of Variance (Lindquist, 1953) for the Absolute Spatial Error Measure on the First Four Blocks of Three Trials

	F Ratios		
Measure	Method	Trials	Methods x Trials
Absolute Spatial Error on Downwind Leg	0.15	6.08[a]	0.46
Absolute Spatial Error on Base Leg	0.28	6.09[a]	0.63
Absolute Spatial Error on Final Leg	3.20	4.19[a]	3.82[b]
Absolute Spatial Error totaled for all 3 Legs	0.0	7.97[a]	0.44

a = $p < .01$; b = $.01 < p < .05$

F ratio for the Method mean square lacked statistical significance at the .05 level. The F ratios for Trials mean square were significant in all cases indicating, what is obvious from the figures, that a learning effect is present. The Methods x Trials interaction, representing a differential learning trend for the two groups, was significant only for the final approach.

Figures 5 and 6 show a tendency for the Control Group to have a slight superiority over the Experimental Group, but the absence of statistically significant main effects urges that little confidence be placed in these differences.

Altitude Error

Measurement. Proficiency in contact landing is intimately associated with having the proper altitude at any particular moment in time. While the spatial error that is derived from the ground track of a landing is primary, it always must be considered in relation to the altitude dimension. The normal or ideal altitude must be considered in relation to a particular X-Y point on the ground pattern, and the upper half of Figure 8 shows the relationship that we defined as ideal for altitude. The ideal altitude control program that was taught the subject was to take off and climb steadily at a rate of 600 feet per minute until an altitude of 900 feet is attained in the vicinity of the Downwind turn. This cruise altitude was to be held until a point about opposite the approach end of the runway was reached (Point A), at which time power was reduced and the descent begun. The ideal altitude values from Point A to touchdown are shown for 10-second intervals, and these also are the same ones that are instrumented in the altitude dimension of the System Programmer. The bottom half of Figure 8 shows a vertical view of an ideal and an actual flight, and error was the measured discrepancy in feet between actual and ideal at each 10-second mark. A subject's score on a leg was the algebraic mean of his altitude errors. A total score for all three legs also was computed for each subject. The 10-second pulsing of the pen of the X-Y plotter and the pen of the altitude recorder were synchronized, and this allowed us to synchronize our measurement in error where each measure of spatial error had a corresponding measure of altitude error at the same moment in time. The algebraic convention gave a plus sign to an altitude reading that was too high, and a negative sign when it was too low.

Figures 9, 10, 11, and 12 present the mean absolute altitude error for the three legs and Total Error. There is a definite learning trend for altitude, although it is less pronounced than for the spatial error. The level of altitude error is higher on the Base and Final Legs than on Downwind, but perhaps this is because the Downwind Leg has a longer segment of straight and level flight which is easier for altitude control, and also because the subject could control more easily from the altimeter which had to be held at a constant 900 feet throughout most of the Downwind Leg. Both the Base and Final Legs probably demanded more image reference throughout periods of continuous descent because the altimeter was continuously changing. The numerical values for the absolute means shown in Figures 9 through 12 are given in Tables 13 and 14 in Appendix C.

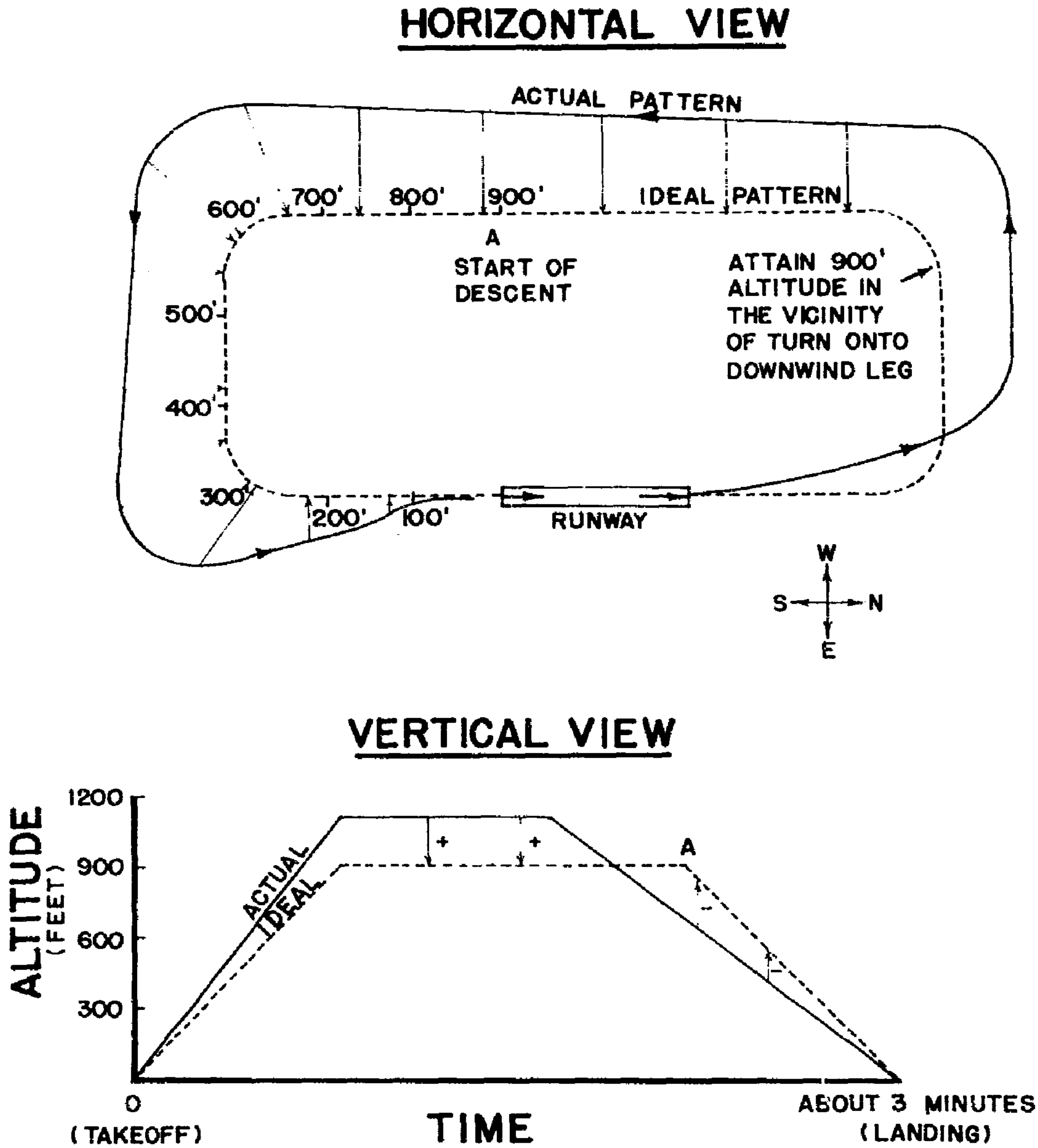

Fig. 8. Schema for measuring altitude error. The horizontal view shows the ideal altitude values for a landing pattern considered in relation to the X-Y ground track. The vertical plan shows how altitude error was measured as deviation of an actual function from a normal or ideal one. The algebraic convention is shown.

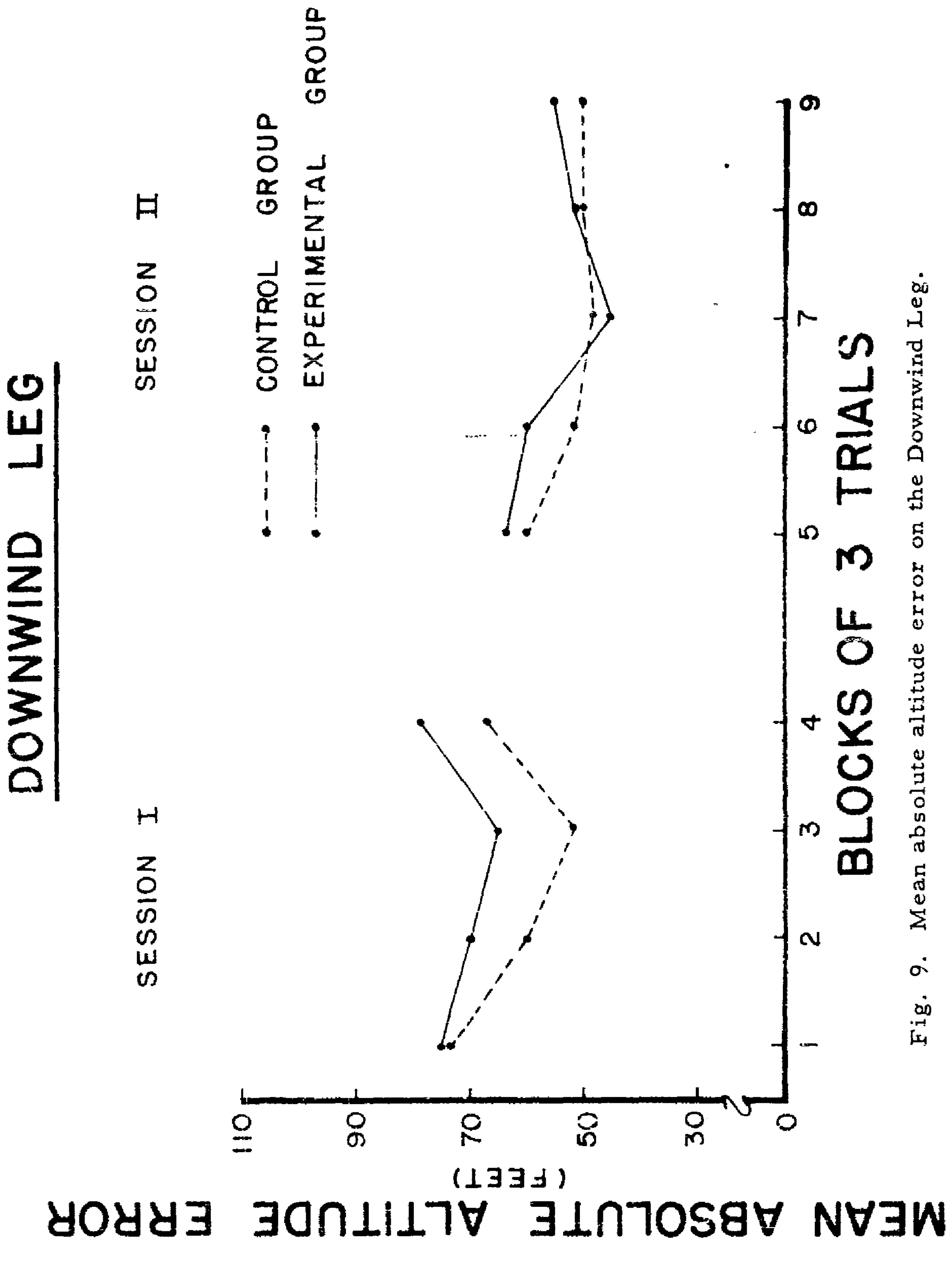

Fig. 9. Mean absolute altitude error on the Downwind Leg.

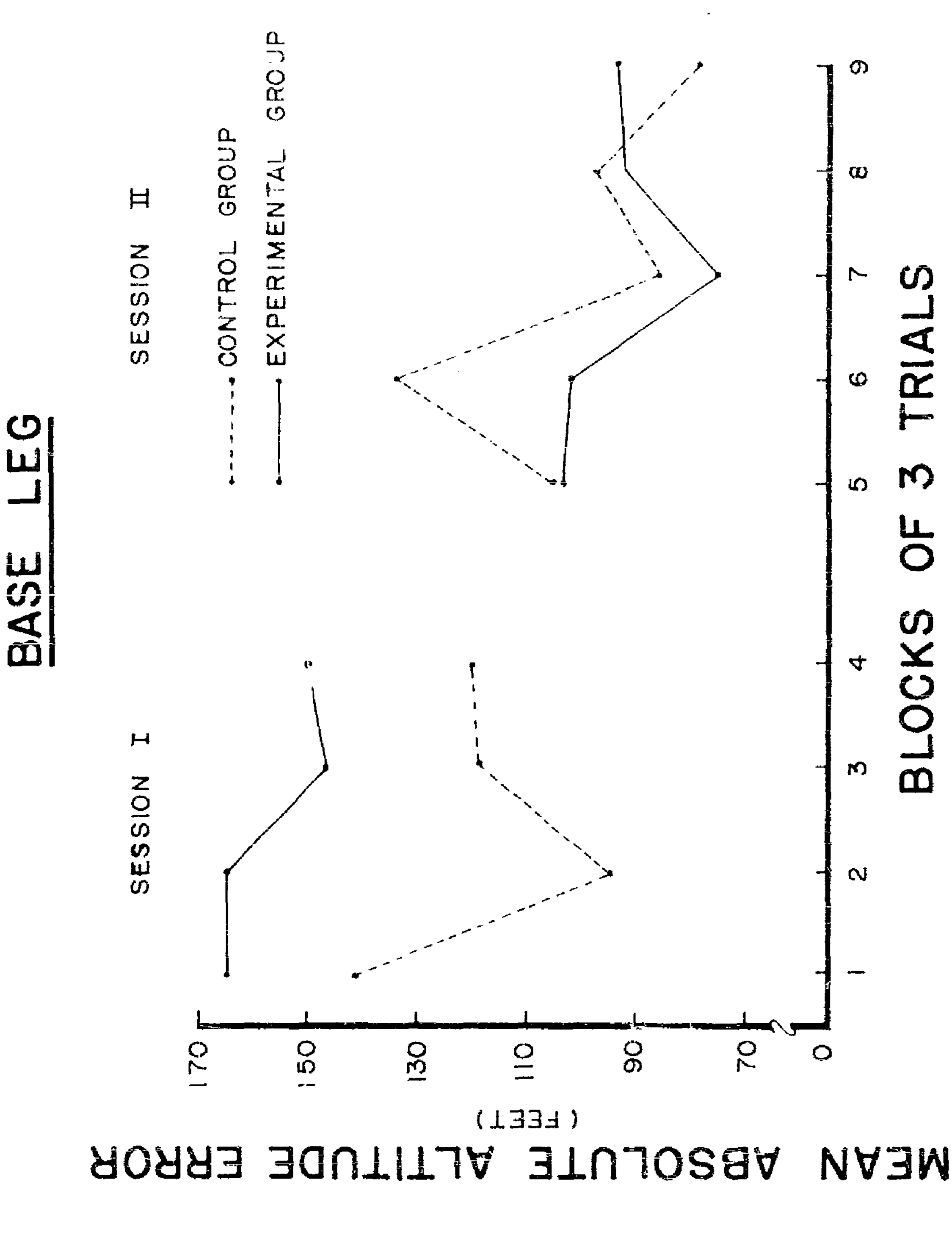

Fig. 10. Mean absolute altitude error on the Base Leg.

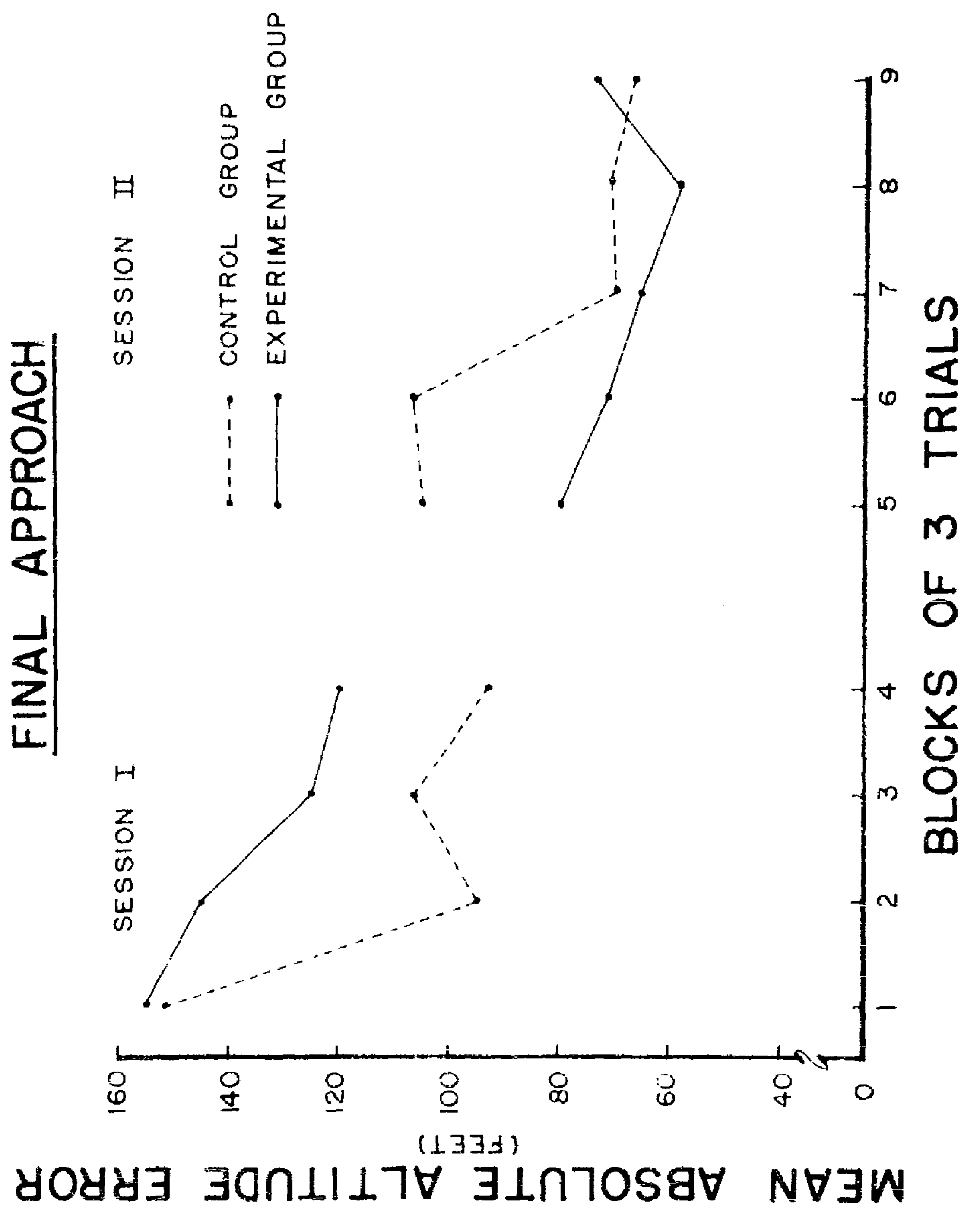

Fig. 11. Mean absolute altitude error on the Final Leg.

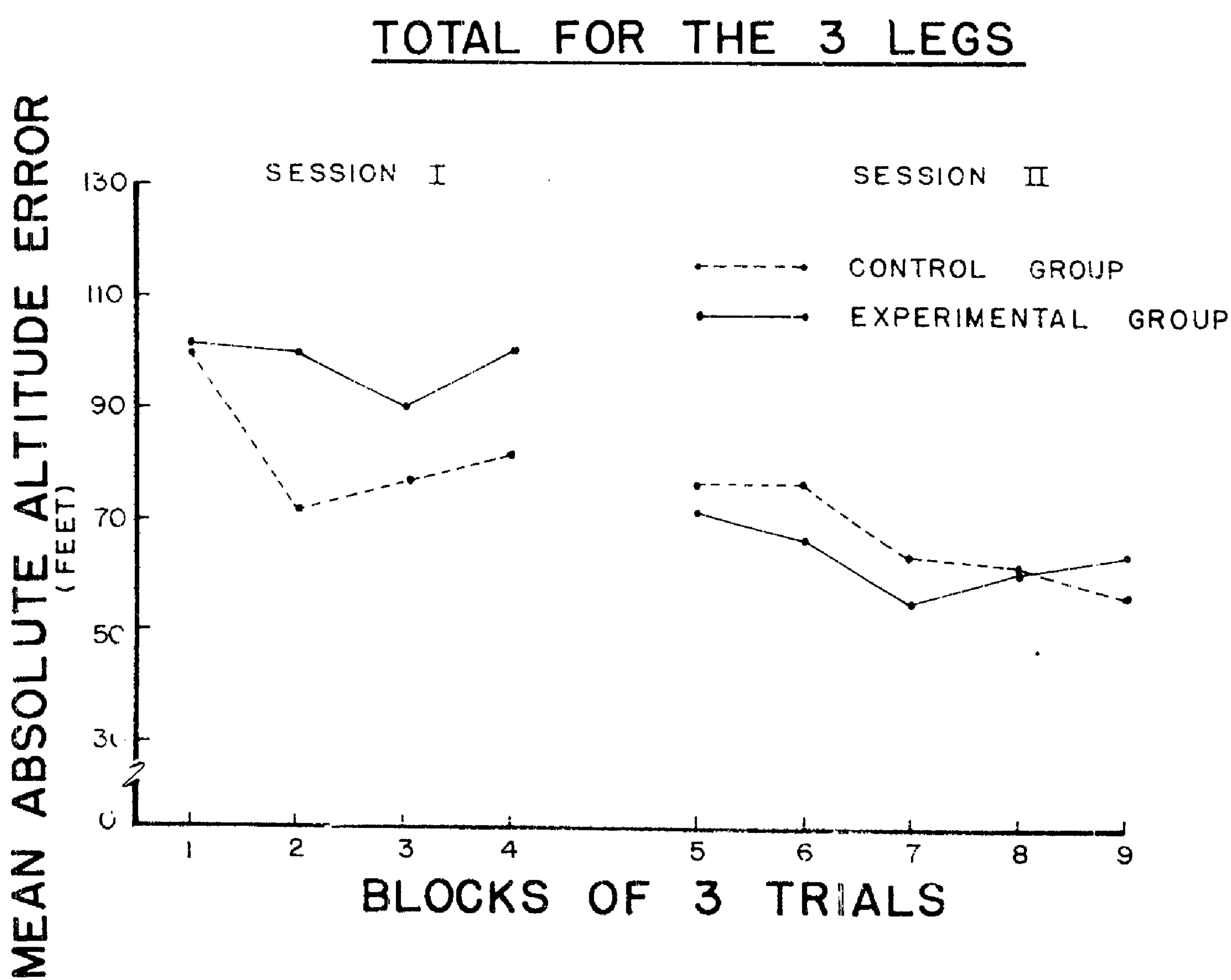

Fig. 12. Mean total absolute altitude error, where the score for a subject was altitude error summated over Downwind, Base, and Final Legs of the pattern.

Tables 15 and 16 in Appendix C present the mean algebraic altitude error for both groups on the nine blocks of trials. The average algebraic error tends to be small, although the values are consistently positive, indicating that subjects had a tendency to fly above the desired vertical flight path.

Four Type I analyses of variance were performed on the first four blocks of trials on the Session I scores of the data presented in Figures 9 through 12, and the results are presented in Table 6. While Figures 9 through 12 show a rather stable tendency for the Control Group to be superior to the Experimental Group, this is borne out statistically for the Base Leg only, where the F ratio for Method mean square is significant between the .01 and the .05 level. Only two of the F ratios for Trials mean square were significant, suggesting that altitude error overall has a less precipitous learning trend than spatial error. The F ratios for the Method x Trials interaction were not significant.

TABLE 6

Results of Type I Analyses of Variance (Lindquist, 1953) for the Absolute Altitude Error Measure in the First Four Blocks of Trials

	F Ratios		
Measure	Method	Trials	Method x Trials
Absolute Altitude Error on Downwind Leg	1.73	3.51[b]	2.41
Absolute Altitude Error on Base Leg	6.03[b*]	1.13	1.27
Absolute Altitude Error on Final Leg	2.45	2.78[b]	0.77
Absolute Altitude Error totaled for all 3 Legs	2.74	2.62	0.94

a = $p < .01$; b = $.01 < p < .05$

*The Experimental Group is inferior to the Control Group.

Terminal Landing Success

Measurement. The data presented in Figures 3 through 12 have dealt with overall error in the horizontal and vertical dimensions of simulated flight. These are important indices of landing proficiency, but clearly the pilot's performance at the termination of the landing sequence is the payoff. Our records of flying performance permitted us to obtain the values of variables necessary for judging the success or the failure of a landing by a subject. The first steps were to find the point in simulated space or on the simulated ground where the subject touched down, or attempted to touch down, and then to determine the airspeed, rate of descent, and heading of the aircraft at this terminal point. The following measures were made for each landing by each subject:

1. The point where the altitude record first reached zero, or, if it was not zero, the point where the subject rounded out and the altitude record was at a minimum, non-zero value. There were occasions when the subject would round out at a non-zero altitude and, when this would happen, the Experimenter would judge this to be the termination of the landing. During the criterion runs the Experimenter would monitor the altitude recorder and the altimeter and, when the subject rounded out at a non-zero altitude value, he considered the landing completed and directed the subject to apply power and go around for the next landing pattern.

2. Find the point in time on the X-Y record (ground position) that corresponded to the point of zero altitude or minimum non-zero altitude. This value was measured in both X and Y, using the approach or south end of the runway as the point of reference, X was considered to be a line running through the center of the runway, being positive in sign if the subject lands short of the runway end, and negative if the subject lands on the runway or beyond. Negative values of Y were to the left or west of the runway centerline, and positive values to the right or east of the centerline. X and Y were measured in

feet, and defined the termination point of the landing with respect to the ground coordinates of the approach end of the runway.

3. The airspeed was computed by making a time-distance calculation from the X-Y record, using the last complete 10-second segment just prior to the termination point.

4. The altitude record was used to compute rate of descent in feet per minute for the same 10-second period used to compute airspeed.

5. Heading in degrees error from 360 (ideal heading) was computed from the X-Y record at the termination point.

These values are only descriptive empirical values, with no implications for success, and must now be held up against a criterion specifying the tolerances for a satisfactory landing. Therefore, the following criteria were adopted for terminal success:

1. Y value within ± 150 feet.
2. X value within the range of zero to -1200 feet.
3. Altitude at zero when both X and Y are satisfied.
4. Airspeed between 100-120 miles per hour.
5. Rate of descent between 400 and 2000 feet per minute.
6. Heading error within ± 10° of 360°.

Using these criteria against which to weigh the actual terminal performance of a subject, each landing was judged successful or unsuccessful. Figure 13 gives the plot of mean per cent successful landings for both groups in blocks of three trials. There is a progressive learning effect shown, with the Control Group showing a slight superiority in Session I. Defining a subject's score for a block of three trials as number of successful landings, a Type I analysis of variance was calculated for the first four blocks of trials (Session I). Neither Methods, Trials, nor Methods x Trials interaction was significant. Tables 19 through 22 in Appendix D give terminal performance data for the two groups.

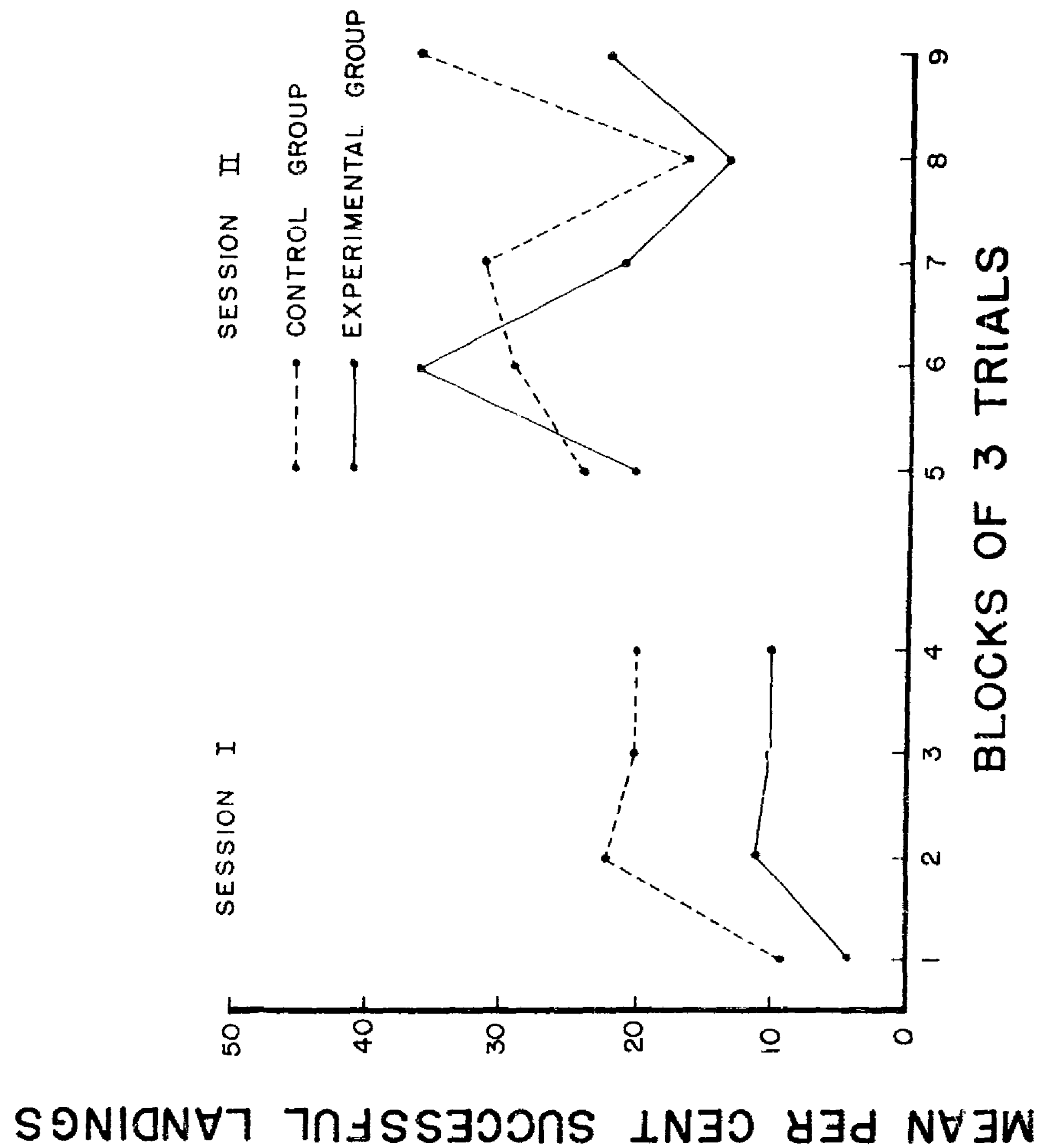

Fig. 13. Mean per cent successful landings for the two groups.

Experienced Pilots

Spatial and Altitude Error. Eight experienced pilots flew 12 simulated landings in the Contact Landing Trainer, and their data are presented primarily for informational purposes to help our understanding of flying behavior in the new Contact Landing Trainer. Figure 14 shows both the mean absolute altitude error and the mean absolute spatial error for the three legs of the landing pattern. One of the most interesting findings is the large absolute spatial error on the first block of three trials. The error levels for both the Downwind and Base Leg run about 50 per cent higher than corresponding data for our naive subjects shown in Figures 4 and 5. This initial decremental tendency is transitory however, because by the second block of three trials the mean absolute spatial error for Downwind and Base are reduced to about one-third of their initial value and tend to decrease even more by the end of the session. Performances on the last block of three trials (No. 4) are about at the same levels as that of the two groups of the main experiment on their last block (No. 9). The mean absolute altitude error shows the experienced pilots performing somewhat better throughout than our naive subjects. The mean values for absolute and algebraic spatial error on each trial block are in Tables 11 and 12 in Appendix B. Notice that the algebraic spatial error initially tends to be large and positive, signifying that the experienced pilots flew patterns that averaged much too wide. Mean values of absolute and algebraic altitude error are in Tables 17 and 18 of Appendix C.

Terminal Landing Success. Tables 23 and 24 in Appendix D give the mean values of variables for computing the per cent correct landings. These per cent values are 59, 63, 56, and 59 for Trial Blocks 1 through 4, respectively. It is noteworthy that the experience of these pilots is clearly evident in their achievement of the various criteria required for successful landing because their levels of per cent correct are much higher than for those of the naive subjects (Figure 13). The simulation, however, may have some shortcomings because, while the per cent correct landings for the experienced pilots is high relative to the naive subjects, it is poor by any realistic expectation we

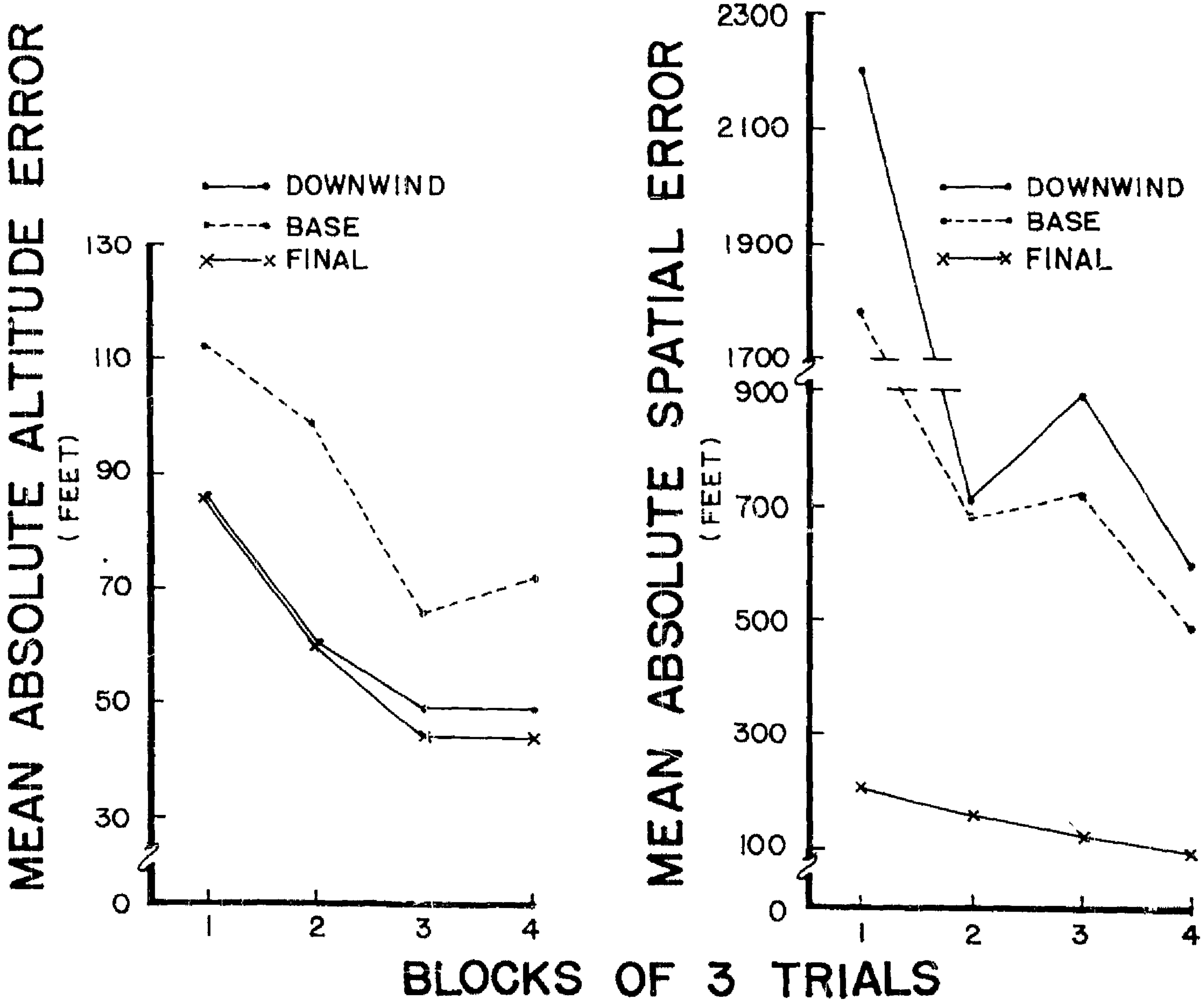

Fig. 14. For the experienced pilots, mean absolute altitude error and mean absolute spatial error on Downwind, Base, and Final Legs.

would have for pilots of this experience level. It must be kept in mind however, that conclusions such as these are made in terms of the criteria which we established for landing success, and these may differ somewhat from one experienced pilot to another, depending on the type of aircraft within which most of his experience was acquired. An explicit experiment that dealt with experience level as a variable could control some of these factors (see next section).

DISCUSSION AND CONCLUSIONS

Main Experiment

The results of the experiment do not support a hypothesis that could be used as a rationale for developing part-training devices that would be simpler than a complex closed-loop arrangement of a flight simulator and a simulation subsystem for contact landing cues. It was hypothesized that mediating perceptual-verbal responses, for establishing the correctness of a contact landing configuration at any moement, could be strengthened by having a subject make evaluations of the presence or absence of a display error, the type of error, and its cause. The failure of pretraining to transfer positively to the whole-task activity of flying simulated contact landings gave no support for the suggestion that simple methods of perceptual pretraining might be developed. Our results are found consistent with those of Creelman (1955) where prior perceptual training from films and a dynamic contact landing display for an SNJ OFT gave no appreciable transfer to flying contact landings in the SNJ aircraft. Creelman concluded that the whole-task method of training, where the subject practices the entire perceptual-motor task, has the most training benefits.

Whenever a difference was observed it generally was in the direction of inferiority for the Experimental Group that had received pretraining. It is difficult to give weight to these differences in the absence of statistical support, but the rather consistent trend can, if nothing else, serve as a basis for hints for further experiments. One explanatory possibility for these small differences is the time-sharing hypothesis where it might be argued that our pretraining exercises gave the subject a tendency to be unduly preoccupied with the visual scene and consequently he failed to time-share his scanning of the contact world adequately with critical cues on the instrument panel. This interpretation is suggested particularly in Figures 9 through 12 showing absolute altitude error. On these four graphs, the Experimental Group is consistently worse than the Control Group and, with altitude being a matter of control with respect to the altimeter, it could suggest inappropriate visual scanning of the instrument panel. Perhaps it is worthwhile to note that the only significant F ratio for Methods variance was absolute altitude error on the Base Leg.

Despite these hints of the role of time-sharing as a variable, a conclusion of no effects from pretraining is the most tenable, and the simplest interpretation in that the hypothesis of the role of learned mediating responses is deficient for the very complex perceptual-motor task of contact flying. Mediation theory seems applicable for discrete motor responses, and the identification of static visual forms, but it may be inappropriate when continuous motor tracking sequences and dynamic visual displays are concerned. On the other hand, the research on mediation and tracking has been quite limited and perhaps it is premature to reject the hypothesis at this time. Certainly the role of mediators for the selection of tracking sequences appears in analysis to be formally the same as when discrete responses are involved. Some initial work in this area by Adams and Creamer (in press) shows that mediating responses play a role in predicting the time of directional changes of a repetitive signal in tracking and can be pretrained. However, their experiment dealt primarily with time perception, and this behavioral process may be more amenable to mediational analysis than interpreting a complex landing display and estimating from it the correctness of an aircraft's position in space. There is a need for additional research on the role of mediating responses and the function they play in transfer of training, both for tracking and other response classes. The topic is one of the most significant areas for practical questions of transfer of training because, if it can be shown that mediating responses are critical for a particular class of learned behavior, then very often verbal labels can be used as the mediators and taught by a variety of simple means.

Our hypothesis still could be sound, with our negative results being a matter of our insufficient knowledge in methods of strengthening mediators sufficiently to induce positive transfer. Perhaps not enough practice was given. A subject of the Experimental Group was given 16 contact landing problems during which time 46 verbal judgments and evaluations were elicited from him. We have no way of knowing whether this was adequate. Nor do we know that the proper kinds of perceptual-verbal pretraining practice were administered. The errors judged may not have been of the correct type or of the appropriate magnitude. Alternatively, and perhaps the simplest explanation of all, is that whatever perceptual pretraining could be accomplished was done with the contact landing film and the accompanying discussion of landing errors. The learning that subsequently took place in the criterion sessions might be more a matter of closed-loop, perceptual-motor learning where a subject's discrimination of error must be associated with patterns of continuous tracking movements. Creelman's conclusions held this to be the fundamental nature of learning to fly contact landing patterns, and our data can be interpreted in the same way. A series of experiments would be needed before all of these factors are understood.

Experienced Pilots

The error trends of the eight experienced pilots are broadly consistent with the perceptual pretraining findings for the subjects of the Experimental Group, and the errors of all our naive subjects in criterion flying of the Contact Landing Trainer, by showing relatively large spatial errors on the Downwind and Base Legs and much less error on Final approach. A provocative feature of the findings is that the experienced pilots had much larger errors on Downwind and Base than the neophytes, and apparently were manifesting negative transfer. The negative transfer proved to be a transitory phenomenon because it disappeared with practice where the pilots, with knowledge of results each time, learned the requirements of the simulated task. Performance on the final approach, and in the per cent of successful landings, revealed positive transfer.

The experienced pilots were included in the research program for broad informational purposes, but their data are stimulating the hypothesis of Phenomenological Equivalence by Lybrand et al (1958a, 1958b) in which they suggested, without the authority of experimental evidence, that visual displays for flight simulators could be validated inversely by determining how the past learning of pilots acquired in in-flight responding to cues of the real world transfer to the visual simulator. Positive transfer would be expected if the cue-response relationships of the simulated system are consistent with those that the pilot has known in flying. But, if the training system is inconsistent with the real world and simulation is poor, zero or negative transfer would be anticipated. Our data from the experienced pilots, showing negative transfer on the initial trials for spatial error on the Downwind and Base Legs, suggest that these aspects of the simulation are poor. The direction of the algebraic error for these stages of the landing pattern is large and positive, showing that they flew a pattern that was much too wide, and this can be interpreted to mean that the runway image was overly magnified and the pilots had to fly a wide pattern in order to have an image size appropriate for the landing patterns that they typically flew (assuming that they were not being extra-cautious with an unfamiliar aircraft and landing task). On the other hand, the simulation variables for final approach and touchdown apparently were much better, because of their good performance with respect to our naive subjects, although the per cents of successful landings were below any reasonable expectation for experienced flyers.

These interpretations of our data in terms of the hypothesis by Lybrand et al are submitted cautiously at this time. The experienced pilots were unfamiliar with our simulated aircraft and its procedures, and a portion of the error level certainly must be ascribed to these interacting variables. An explicit experimental design to test the hypothesis first should give perceptual pretraining problems with the System Programmer to solely test the errors of visual interpretation, and it should be followed with familiarization instrument training flights in the Link trainer of the system before further tests were made for errors in actually flying the total system. Furthermore, and crucial for the hypothesis, would be the use of experimental groups differentiated by the flying experience of the member subjects. The transfer of training, negative or positive, should be a systematic function of the amount of experience that pilots have had with the task in the real world, as well as the goodness of simulation. Experimental support for the hypothesis of Phenomenological Equivalence could have broad significance for the validation of visual simulation equipment because it now appears that the conventional transfer of training experiment is no longer feasible for the complex classes of visual display problems that will be simulated for flight training in the future. The transfer of training design, which conventionally occurs to psychologists when they think of validating a flight simulator, requires measures of flying proficiency for criterion indices that reliably indicate where the pilot positions an aircraft with respect to contact cues. While in principle the technology exists for psychologists to objectively measure the position of an aircraft with respect to points and lines of the external world, in practice the technical elaborateness is forbidding and is almost never attempted. A new validation technique would be a significant advance for the methodology of training research.

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TECHNICAL APPENDICES

A Five Representative Data Sheets Used for Scoring the Perceptual-Verbal Pretraining Given the Experimental Group in the 16 Programmed Landing Patterns.

B Tables 7 through 12. Mean Absolute and Algebraic Spatial Error for Each Group on Each Block of Three Trials.

C Tables 13 through 18. Mean Absolute and Algebraic Altitude Error for Each Group on Each Block of Three Trials.

D Tables 19 through 24. Mean Values of Variables Used in Determining Point of Landing Termination. Also Per Cent Correct Landings Are Given. For Each Group on Each Block of Three Trials.

APPENDIX A

Five representative data sheets used for scoring the perceptual-verbal pretraining given the Experimental Group in the 16 programmed landing patterns.

APPENDIX A

Data Sheet No. 1

Subject ______________________

Programmed Error: None. Normal Pattern.

Positions of Programmer Switches.

Downwind:	Normal
Descent:	Normal
Base:	Normal
Final:	Normal

Pilot Judgment on Crosswind Leg.

	Correct Response	Score 0 or 3
Correct Pattern?	Yes	________

Pilot Judgment on Downwind Leg (before descent begins)

Correct Pattern?	Yes	________

Pilot Judgment on Final Leg

Correct Pattern?	Yes	________

Comment

APPENDIX A

Data Sheet No. 3

Subject ____________________

Programmed Error: Late Turn onto Final Leg.

Positions of Programmer Switches.

Downwind:	Normal
Descent:	Normal
Base:	Normal
Final:	Late

Pilot Judgment on Base Leg

	Correct Response	Score 0 or 3
Correct Pattern:	Yes	______

Pilot Judgment on Final Leg

		Score 0 or 1
1. Correct Pattern?	No	______
2. Nature of Error:	Runway to the Left (or too low)	______
3. Cause of Error:	Late turn onto Final Leg	______

Comment

APPENDIX A

Data Sheet No. 4

Subject ____________________

Programmed Error: Early Turn onto Downwind Leg.

Positions of Programmer Switches.

Downwind:	Early
Descent:	Normal
Base:	Normal
Final:	Normal

Pilot Judgment on Crosswind Leg

	Correct Response	Score 0 or 3
Correct Pattern:	Yes	______

Pilot Judgment on Downwind Leg (before descent begins)

		Score 0 or 1
1. Correct Pattern?	No	______
2. Nature of Error:	Too close to runway	______
3. Cause of Error:	Early turn onto Downwind Leg	______

Pilot Judgment on Final Leg

1. Correct Pattern?	No	______
2. Nature of Error:	Too high	______
3. Cause of Error:	Early turn onto Downwind Leg	______

Comments

APPENDIX A

Data Sheet No. 5

Subject ____________________

Programmed Error: Late turn onto Base Leg.

Positions of Programmer Switches.

Downwind:	Normal
Descent:	Normal
Base:	Late
Final:	Normal

Pilot Judgment on Crosswind Leg

	Correct Response	Score 0 or 3
Correct Pattern?	Yes	______

Pilot Judgment on Base Leg

		Score 0 or 1
1. Correct Pattern?	No	______
2. Nature of Error:	Too far out (or too low)	______
3. Cause of Error:	Late Turn onto Base Leg	______

Pilot Judgment on Final Leg

1. Correct Pattern?	No	______
2. Nature of Error:	Too low	______
3. Cause of Error:	Late Turn onto Base Leg	______

Comments

APPENDIX A

Data Sheet No. 16

Subject ____________________

Programmed Error: Late Descent.

Positions of Programmer Switches.

Downwind:	Normal
Descent:	Late
Base:	Normal
Final:	Normal

Pilot Judgment on Downwind Leg (before descent begins)

	Correct Response	Score 0 or 3
Correct Pattern?	Yes	______

Pilot Judgment on Base Leg		Score 0 or 1
1. Correct Pattern?	No	______
2. Nature of Error:	Too high	______
3. Cause of Error:	Late descent	______

Pilot Judgment on Final Leg

1. Correct Pattern?	No	______
2. Nature of Error:	Too high	______
3. Cause of Error:	Late descent	______

Comments

APPENDIX B

Tables 7 through 12. Mean absolute and algebraic spatial error for each group on each block of three trials.

APPENDIX B

TABLE 7

Mean Absolute Spatial Error in Feet for the Control Group

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	1317	1170	527	1093
2	900	707	247	707
3	1017	593	207	767
4	983	647	270	760
5	853	683	203	690
6	733	570	153	583
7	693	627	203	610
8	733	510	200	583
9	653	523	137	540

APPENDIX B

TABLE 8

Mean Absolute Spatial Error in Feet for the Experimental Group

Blocks of 3 Trials	Leg			Total
	Downwind	Base	Final	
1	1373	1062	443	1073
2	944	832	486	820
3	927	800	419	783
4	773	648	390	667
5	1010	720	343	810
6	687	917	200	603
7	913	650	190	698
8	617	593	217	523
9	583	600	217	507

APPENDIX B

TABLE 9

Mean Algebraic Spatial Error in Feet for the Control Group

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	103	480	143	677
2	587	313	113	423
3	333	33	63	233
4	287	170	120	220
5	363	243	-80	237
6	210	130	- 7	137
7	347	360	100	280
8	363	357	90	297
9	213	363	90	203

APPENDIX B

TABLE 10

Mean Algebraic Spatial Error in Feet for the Experimental Group

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	590	428	103	350
2	-125	573	146	-83
3	73	537	317	103
4	37	416	133	33
5	600	430	-160	350
6	120	580	- 20	120
7	510	390	40	330
8	180	320	40	160
9	170	280	40	160

APPENDIX B

TABLE 11

Mean Absolute Spatial Error in Feet for the Experienced Pilots

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	2203	1793	200	1680
2	713	677	158	647
3	890	720	120	693
4	593	487	94	490

APPENDIX B

TABLE 12

Mean Algebraic Spatial Error in Feet for Experienced Pilots

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	2127	1510	110	1540
2	210	327	-17	127
3	603	567	37	463
4	193	83	27	127

APPENDIX C

.Tables 13 through 18. Mean absolute and algebraic altitude error for each group on each block of three trials.

APPENDIX C

TABLE 13

Mean Absolute Altitude Error in Feet for the Control Group

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	73	192	152	100
2	60	95	95	72
3	52	118	107	77
4	67	120	93	82
5	60	105	105	77
6	52	133	107	77
7	48	85	70	63
8	50	97	72	62
9	50	78	67	57

APPENDIX C

TABLE 14

Mean Absolute Altitude Error in Feet for the Experimental Group

Blocks of 3 Trials	Leg: Downwind	Base	Final	Total
1	75	165	155	102
2	70	165	145	100
3	65	147	125	90
4	78	150	120	100
5	63	103	80	72
6	60	102	72	67
7	45	75	65	55
8	52	92	58	60
9	55	93	73	63

APPENDIX C

TABLE 15

Mean Algebraic Altitude Error in Feet for the Control Group

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	35	80	97	58
2	20	48	58	30
3	17	63	80	37
4	10	77	57	32
5	22	67	70	37
6	23	100	92	50
7	18	50	57	32
8	22	47	37	30
9	15	47	38	27

APPENDIX C

TABLE 16

Mean Algebraic Altitude Error in Feet for the Experimental Group

Blocks of 3 Trials	Leg: Downwind	Base	Final	Total
1	20	65	93	43
2	25	130	120	60
3	30	78	90	45
4	27	80	70	47
5	25	42	42	28
6	27	52	33	30
7	25	15	30	20
8	22	33	30	27
9	3	-3	8	3

APPENDIX C

TABLE 17

Mean Absolute Altitude Error in Feet for the Experienced Pilots

Blocks of 3 Trials	Leg: Downwind	Leg: Base	Leg: Final	Total
1	85	112	85	88
2	60	98	60	67
3	48	65	43	52
4	48	72	43	52

APPENDIX C

TABLE 18

Mean Algebraic Altitude Error in Feet for the Experienced Pilots

Blocks of 3 Trials	Downwind	Base	Final	Total
1	73	95	63	72
2	48	88	40	52
3	28	15	8	23
4	20	5	23	18

APPENDIX D

Tables 19 through 24. Mean values of variables used in determining point of landing termination. Also per cent correct landings are given. For each group on each block of three trials.

APPENDIX D

TABLE 19

Mean Absolute and Algebraic Error in X and Y for Control Group at Point of Landing Termination

Blocks of 3 Trials	Error in X (feet)		Error in Y (feet)	
	Absolute	Algebraic	Absolute	Algebraic
1	1352	- 597	446	186
2	1073	- 713	198	173
3	1157	-1030	121	61
4	1192	- 874	181	137
5	1106	- 906	137	14
6	880	- 769	134	68
7	998	- 836	208	192
8	952	- 769	172	121
9	920	- 869	146	108

APPENDIX D

TABLE 20

Mean Values of Certain Key Variables for Control Group at Point of Landing Termination. The Value in Parenthesis in the Altitude Column is Per Cent of Landings for Group that Terminated at Zero Altitude. Per Cent of Landings Judged to be Successful is Given in Last Column

Blocks of 3 Trials	Altitude (feet)	Airspeed (MPH)	Rate of Descent (feet per minute)	Heading (degrees)	Per Cent Correct Landings
1	112 (47)	118	672	6	9
2	45 (67)	117	759	7	22
3	40 (69)	116	791	4	20
4	18 (80)	116	846	7	20
5	43 (67)	115	769	3	24
6	58 (62)	114	761	4	29
7	23 (73)	113	742	4	31
8	23 (67)	116	736	4	16
9	13 (80)	114	656	3	36

APPENDIX D

TABLE 21

Mean Absolute and Algebraic Error in X and Y for Experimental Group at Point of Landing Termination

Blocks of 3 Trials	Error in X (feet)		Error in Y (feet)	
	Absolute	Algebraic	Absolute	Algebraic
1	1302	- 887	376	113
2	1102	-1031	374	219
3	1172	- 349	408	344
4	1412	-1010	395	98
5	951	- 722	231	- 91
6	822	- 691	173	49
7	924	- 701	159	76
8	948	- 746	157	88
9	1204	- 829	236	56

APPENDIX D

TABLE 22

Mean Values of Certain Key Variables for Experimental Group at Point of Landing Termination. The Value in Parenthesis in the Altitude Column is Per Cent of Landings for Group that Terminated at Zero Altitude. Per Cent of Landings Judged to be Successful is Given in Last Column

Blocks of 3 Trials	Altitude (feet)	Airspeed (MPH)	Rate of Descent (feet per minute)	Heading (degrees)	Per Cent Correct Landings
1	107 (40)	123	683	6	4
2	99 (45)	118	728	7	11
3	108 (43)	119	643	8	10
4	46 (66)	120	837	7	10
5	36 (67)	116	761	5	20
6	33 (58)	113	684	4	36
7	31 (67)	114	646	5	21
8	27 (58)	114	667	5	13
9	19 (84)	115	612	5	22

APPENDIX D

TABLE 23

Mean Absolute and Algebraic Error in X and Y for Experienced Pilots at Point of Landing Termination

Blocks of 3 Trials	Error in X (feet)		Error in Y (feet)	
	Absolute	Algebraic	Absolute	Algebraic
1	707	-596	68	43
2	626	-548	93	70
3	502	-387	98	94
4	646	-594	78	74

APPENDIX D

TABLE 24

Mean Values of Certain Key Variables for Experienced Pilots at Point of Landing Termination. The Value in Parenthesis in the Altitude Column is Per Cent of Landings for Group that Terminated at Zero Altitude. Per Cent of Landings Judged to be Successful is Given in Last Column

Blocks of 3 Trials	Altitude (feet)	Airspeed (MPH)	Rate of Descent (feet per minute)	Heading (degrees)	Per Cent Correct Landings
1	4 (96)	116	902	3	59
2	3 (96)	117	898	3	63
3	6 (89)	115	755	4	56
4	1 (96)	114	751	3	59

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